An Investigation of the Connections Between Adult Student Success, Satisfaction, and Learning Preferences and Usable Interface Design of Web-Based Educational Resources

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Jason E. Rollins

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Abstract

An Investigation of the Connections Between Adult Student Success, Satisfaction, and Learning Preferences and Usable Interface Design of Web-Based Educational Resources

Jason E. Rollins

Craig N. Bach, PhD

Whether used as a tool to enhance a traditional classroom, or as the delivery mechanism for Web-based distance learning, the recent impact of the Internet on adult higher education has been substantial. From this, one of the most important emerging challenges to educators is harnessing and adapting the power of these technologies to suit a broad range of adult learners. With the goal of addressing this challenge, this dissertation examined the connections among adult student's use of Web-based educational resources, the visual design and usability of these applications, student satisfaction, and learning preferences.

In this mixed method study of adult learners, 50 volunteer subjects were tested interacting with several different Web sites. Student learning preferences, interface usability, and student self-efficacy and satisfaction with their use of the Web were observed and measured to determine the significance and scope of these associations. Test results were also subjected to linear regression analysis using SAS software.

Investigation findings validated the research hypotheses and provided evidence that in many cases, adult students interact differently, and have varying levels of success and satisfaction, with Web-based learning environments depending on both their specific learning style and the visual design of these resources. Test subjects with different

learning style strengths had unique preferences for individual interface elements and navigation designs but most perceived Web sites with clearly organized navigation menus, effective search features, and lists of content choices to be the most attractive and effective in facilitating learning. The most significant quantitative connections proved to be between learners with strong preferences on the Visual-Verbal dimension of The Felder / Silverman Inventory of Learning Styles (ILS) and correspondingly higher use of either graphic (for visual learners) or text (for verbal learners) interface elements. As well, the connection between higher computer self-efficacy as scored on the Eachus / Cassidy instrument and general subjective satisfaction with the test sites was supported. Also, general design recommendations were made for developing Web-based learning resources based on research findings. Results from this study may be useful to instructors, designers, and researchers working with Web-based educational applications.

Chapter I: Overview and Purpose of the Study

Introduction

The Word Wide Web now has a major presence in adult educational settings and is widely lauded by educators as a vehicle for promoting learning and broadening participation in formal higher education. Whether used as a tool to enhance a traditional classroom, or as the delivery mechanism for Web-based, distance learning, the recent impact of the Internet on adult education has been substantial. From this, one of the most important emerging challenges to educators is harnessing and adapting the power of these technologies to suit a broad range of adult learners. The visual design and usability of these educational applications has shown to be vital to their success as viable learning aids as the graphic interface serves as the primary channel through which learners interact with (and potentially benefit from) the technology. However, the specific connections between successful student learning and the visual design of Web-based educational material is an area that has not been thoroughly explored and additional research is necessary to identify the salient issues affecting these interactions.

With the goal of addressing this challenge, this dissertation study examined the relationship between adult student's use of the World Wide Web, visual interface usability of Web-based educational resources, and student learning preferences. The objective of this project was to clarify these connections and make general recommendations for improvements in Web design based on research findings. Adult student learning preferences, Web navigation and interface usability, and student success and satisfaction with their use of the Web were observed and measured to determine the significance and scope of these correlations.

This investigation was a qualitative and quantitative *mixed method* study of adult learners in graduate level courses that regularly used the Web for course instruction, assignments, communication, and research. The study: 1. Determined the nature and strength of the relationship between adult student learning preferences and the usability of navigational and interface elements of educational Web sites. 2. Investigated the connection between adult student success and satisfaction with the use of the instructional Web sites.

The experimental design methodology used a combined, quantitative and qualitative *between methods* study approach of a *dominant-less dominant design* with the quantitative paradigm being the *dominant* element and the qualitative being the *less dominant* perspective. The research design paradigm assumptions for this study employ a pragmatist approach of methodological appropriateness and utility asserting that the most efficient and effective use of both quantitative and qualitative paradigms should be employed in understanding phenomena (Creswell, 1994; Patton, 1997). The contemporary educational philosophy of *constructivism*, particularly the idea of students' capacities to integrate knowledge and construct their own meaning, served as a principal informer of this project. The natural-science-oriented paradigm of hypothetico-deductive methodology also influenced the research, as this is the primary method of inquiry adopted by usability testing methods in the fields of Usability Engineering and Human Computer Interaction (HCI). While methodologically somewhat different, philosophically this combination of research paradigms reflects the goal-based approach of both constructivism and computer usability and the multi-disciplinary nature of the myriad, overlapping fields of study under inquiry.

Quantitative data from usability tests, satisfaction surveys, and learning preference instruments, were combined with qualitative data from interviews and observation to attempt to present a robust and balanced view of the test phenomena. The *quantitative, substantive theoretical perspective* was rooted in three primary hypotheses:

- Hypothesis 1: Visual design and navigation elements of Web-based educational resources relate directly to the needs of specific adult student learner-types
- Hypothesis 2: Screen elements and organization schemes that support many learner types show a direct correlation to greater success and subjective satisfaction among adult learners using Web-based educational resources.
- Hypothesis 3: There is a connection between the unique concerns of adult students and Web-based educational material that should be improved through the tailoring of the design of visual interfaces of such material.

The goal of this study was to contribute to the field of instructional technology with recommendations for the improvement of interface design for Web-based educational material and to the broader area of understanding on adult learning and student learning preferences. This study provides baseline data to determine the degree to which the hypotheses are true to the test population by developing a robust picture of learning styles and usability measurements and assessments. The results developed by this study allow conclusions to be made as to general recommendations and guidelines for Web interface design with consideration for adult student's particular learning needs.

As the hypotheses state, in this study there is a presumed connection between adult student learning preferences, Web interface usability, and student success and satisfaction with Web-based educational resources. This connection is supported to some extent in a growing number of recent studies (see Becker & Dwyer, 1998; Buch & Sena, 2001; Ching-Chun, 1998; Clark & Lyons, 1999; Curry, et. al., 1999; Cushing, 1998; Day, Raven, & Newman, 1998; Digilio, 1998; Felder, 1996; Hu, Reed, & Nelson, 1999; Kettanurak, Ramamurthy, & Haseman, 2001; Lucas, 1999; Martinez, 1999; McLoughlin, 1999; Robotham, 1999) although it has not been fully developed.

For example, course-related multimedia delivered over the Web has been enhanced successfully by employing the Felder / Silverman learning style instrument to determine the attitudes of different learner types toward different features of instructional modules. Studies conducted by Felder (1996) of graduate engineering students show that sensing and visual learners rated demonstrations highly; sensing learners liked having access to derivations of equations and active, sensing, and visual learners preferred multimedia more than their reflective, intuitive, and verbal counterparts did. As well, Clark and Lyons (1999) found, in their analysis of Web Based Training (WBT) for adults that instruction is more effective when based on an analysis of the intended learners and of the jobs the learners are trying to perform. McLoughlin (1999), in her meta-analysis of recent studies and classic literature on learning preferences, identified many consistent trends supporting the value of learning and cognitive style research when applied in practical applications related to technology.

Most current research on Web-based education does not focus on specific connections between usability and visual design of Web sites as linked to student learning preferences although some researchers have begun to explore this idea. Martinez (1999) saw, by analyzing interactions in several Web environments, that learning orientation is a significant factor relating to student satisfaction with Web use. Day, Raven, and Newman (1999) found that a Web-based class in technical communication that allowed students to organize course material according to their preferences had significantly more positive attitudes toward writing compared to a class that did not have this flexibility; but, they found no specific correlation between student learning preference and achievement or success. This investigation builds on the existing work of these studies and considers adult student learning preferences as connected to both learning success and subjective satisfaction.

The connection between usability of Web sites and the unique needs of adult students is also supported in recent literature but has not been fully explored. Knowles (1990) asserts that an understanding of the life experience, self-direction, and orientation to practical application of adult learners is crucial to their ability to master curriculum content within the more flexible class structures enabled by technology-enhanced education. Digilio (1998) discusses characteristics of adult learners and suggests that Web-based instruction provides the flexibility to meet many of the particular constraints, motivations, and learning preferences of adult students. King (1998) agrees, asserting that adult students and their instructors are at the forefront of innovative uses of the Web to overcome the time and space constraints of a conventional classroom and to experiment with new forms of self-directed and group learning.

Additionally, visual design and interface usability was examined as it is recognized that these attributes are essential elements in the delivery of Web-based instruction (see Horton, 2000; King, 1998; Nielsen, 1999; Norman, 1994; Marchionini, 1997). Nielsen is explicit about the connection; he defines usability as “supporting the user’s task…making it easy for people to do what they want to do” (Nielsen, 1995, p. 26). He breaks his definition of Web usability into five components the first is “ease of learning.” Nielsen’s definition also includes “efficiency of use”, “ease of memorization”, “few errors”, and “subjectively pleasing” (Nielsen, 1994). Other authors (see Horton, 2000; King, 1998, Norman, 1994; Wood, 1998) make recommendations for more usable Web site design that imply, if not outright state, a connection between the learning needs of students, the visual organization and usability of Web site design, and the educational effectiveness of Web-based instruction. A sample of these suggestions support this study and include: match the language and design of the site to the skills and needs of its intended audience; keep the course objectives and goals in mind, and omit any material that does not support them; avoid forcing the user to navigate through too many levels of menus or links; provide readily available navigational buttons or links on every page.

The findings of this investigation support the assertion that the usability attribute of *subjective satisfaction* as a component of Web-based educational material may be the area where there are the strongest connections between student learning preferences and usability. Based on available research, it is my belief that learning style preferences, adult learning attitudes toward formal educational situations, computer self-efficacy, individual mental models, and adult student performance using technology all contribute to an individual’s subjective perception of the value of an educational Web site.

This study was conducted at Drexel University in Philadelphia, Pennsylvania. The investigation focused on adult students in graduate level courses and attempted to determine the nature and extent of the connections among student learning style preferences, Web interface design, and adult student success and subjective satisfaction with the use of the Web for course related work. I believe that there is a significant connection among these factors and that by analyzing research findings from studying them recommendations can be made for future improvements to Web interface usability for adult students.

Definition of Terms

The definitions given are representative of the prevailing use of the terms among academic researchers and practicing educational Web site designers. In most cases, a single author’s judgment that best represents the widespread and accepted definition of the term is cited.

Adult Learner: is an individual who meets one or more of the following criteria: defines oneself primarily as something other than a student; has taken on mature responsibilities at an age when typically one would be principally focused on schooling;

is of a non-traditional age for a college or university student (typically age 25 or older). This definition synthesizes some of the ideas of Knowles and Brookfield but should be largely viewed as an original contribution of this research study.

Andragogy: is the predominant modern theory of adult learning. Codified by Knowles in the 1970's, andragogy includes six central principles: the need to know, the learner's self-concept, the role of the learner's experiences, readiness to learn, orientation to learning, and motivation (Knowles, 1990).

Cognitive Theory: a psychological theory emphasizing mental processes. Cognitive theory contends that learning is based on how the learner processes information. Cognitive theorists believe that observable behaviors are the result of the internal processes and cognitive styles of the learner. Much of the work of Piaget, Kolb and others is founded in the Cognitive Theoretical tradition

Constructivism: is a broad-based educational theory incorporating elements of philosophy, psychology, and sociological research that approaches learning from a holistic stance and is founded in the work of Piaget, Vygotsky, Guilford and Bloom. Constructivism proposes that students' capacities to integrate knowledge and construct their own meaning is a more effective approach to developing conceptual understanding than the static view of knowledge and rote learning presented by the contrasting views of Behaviorism (Hyerle, 1996).

Graphical User Interface (GUI): is a computer software display format that enables users to choose commands, start programs and see other options by pointing to pictorial representations and list of menus on a screen. Choices are generally activated using a keyboard or mouse. GUIs serve as the environment in which a user interacts directly with the computer and often masks the underlying operating system. The Apple Macintosh and Microsoft Windows operating systems are examples of popular GUIs (Woodcock, 1994).

Human Computer Interaction (HCI): the academic field that explores theories that explain the interactions among humans and computers and the interfaces that support these interactions. HCI is strongly influenced by psychological, sociological, and communication theory (Marchionni, 1997).

Human Computer Interface: is defined as both the act of a human interacting with a computer and the portion of a computer program with which a person interacts (also User Interface). Contemporary interfaces are either *command line* interfaces that require a user to type commands into a keyboard and read results as text on a screen, or *graphical user interfaces* that represent information graphically and are accessed through a keyboard and a pointing device (mouse, trackball, etc.) (Woodcock, 1994).

Hypermedia: is computerized media that allows for multiple linking and virtual connections among related files, documents and environments. Hypermedia environments are sometimes distinguished from multimedia environments in their inclusion of implicit navigation (Evans & Edwards, 1999).

Information Design: is a design discipline that focuses on the clear and effective presentation of graphical and textual information. It involves a multi and inter-disciplinary approach to communication, combining skills from graphic design, technical and non-technical authoring, psychology, communication theory and cultural studies (Tufte, 1983).

Interface Element: any individual function control, text, multimedia or graphic icon or screen element in a graphical user interface. Interface elements are the basic components that comprise a user interface and typically have an application function or operation associated with them (Stickney, et. al., 1999).

Instructional Systems Design (ISD): is a method for developing training that includes needs analysis, understanding users and what they know, understanding the tasks they need to know and developing training material to bridge this gap. ISD is typically developed after a product for which training is needed has been designed (Hackos & Redish, 1998).

Learning Preferences (Also Learning Styles, Cognitive Styles): Learning preferences deal with characteristic styles of learning and it is commonly accepted (see Knowles, 1990; Kolb, 1984) that students have different learning styles defined by characteristic strengths and preferences in the ways they appropriate and process information. Although there is considerable debate over learning style theory and practice in the educational community, learning style instruments are often used in studies to aid in classification of objective data collection, as is accepted practice in adult learning research.

Mental models: are representations of reality that individuals use to understand specific phenomena. People often form internal mental models to help provide predictive and explanatory power for understanding interactions with the environment, with others, and with the artifacts of technology. Mental models are an important element of many HCI, and instructional design theories (Gentner & Stevens, 1983).

Minimalism: Minimalism is a contemporary framework for the design of instruction especially training materials for computer users built on the theoretical foundations of constructivism. The critical idea of minimalist theory is to minimize the extent to which instructional materials obstruct learning and focus the design on activities that support learner-directed activity and accomplishment (Carroll, 1990).

Multimedia: is a computerized media environment or application that includes multiple types of digital media (sound, video, animation, etc.) and is organized using explicit navigational features (Evans & Edwards, 1999). The use of directive, explicit navigation instead of implicit navigational links is a point that some researchers view as a distinction between Multimedia and Hypermedia. However, there are many researchers who do not make this same distinction. Nielsen (1994) considers multimedia systems to be those that mainly display media, such as video, and hypermedia systems to be more than this in that they allow users to navigate links among units of information.

Open System: in computer software, is an application, environment or system that is not self-contained and may include hyperlinks, content, or functionality from a source outside of the application. Most Web sites are examples of open systems when they include links to, or can be linked from, other sites (Evans & Edwards, 1999).

Self-Efficacy: is a component of social cognitive theory defined as the belief in one's capabilities to organize and execute the sources of action required to manage prospective situations. Proposed by Bandura as a model of personal expectations derived from four principal sources of information: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. Factors influencing the cognitive processing of efficacy information arise from inactive, vicarious, exhortative, and emotive sources (Bandura, 1986).

Subjective Satisfaction: is one of the five primary attributes of usability of a computer system. Subjective satisfaction refers to how pleasant a system is to use as demonstrated by test users. Subjective satisfaction can be especially important to researchers attempting to measure general attitudes of users towards specific systems or system attributes as preferences, attitudes, and performance using technology all contribute to an individual's subjective perception of the value of a computer system (Nielsen, 1994).

Usability Engineering: is the formal study of usability that developed out of research on human factors, which looks at the way individuals interact with their environment. It has evolved into a multi-disciplinary engineering field that uses scientific study and task analysis methodology based on established standards of measurement and evaluation. Usability engineering uses objective observational techniques to identify deficiencies in the usefulness of products and strives to improve product usability by focusing on user needs, empirical measurement, and an iterative design approach (Nielsen, 1994).

Web-based Training (WBT): educational and training material formally delivered via the World Wide Web. WBT typically includes the ability to link to other Web sites, to use dynamic search engines, and to update and correct materials easily. WBT is often designed to be used by both casual and directed learners and can be self-paced (Fleming, 1998; Horton, 1999). Although WBT is sometimes used to distinguish between professional and technical training material and university-based on-line courses, for the purposes of this study, Computer-based Instruction, Web-based Training, Web-based Instruction, and all similar terms are used interchangeably as the subtleties of variety in definitions do not warrant differentiation in my view.

World Wide Web (the Web): is the collection of publicly available hypermedia and multimedia information of the vast interconnected network of the Internet. The Web is a unique, content-rich convergence of hypertext, the Internet, and multimedia (December & Randall, 1994).

Research Hypotheses

This investigation is a mixed method study with the primary research viewpoint based on a quantitative, substantive theoretical perspective rooted in three hypotheses:

- Hypothesis 1: There is a strong correlation between observed learning-types and the use of specific navigation elements of Web-based educational resources.
- Hypothesis 2: Screen elements and visual design schemes contribute to the success and subjective satisfaction of adult learners using Web-based educational resources.

- Hypothesis 3: There is a connection between the needs of adult students and Web-based educational material that should be positively improved through the tailoring of the design of visual interfaces of such material.

Significance of the Study

This investigation produced evidence in support of the research hypotheses by illuminating the scope and magnitude of the connections between adult learning styles and usable visual design of interfaces for Web-based course material. This study focused on the connections between adult students with specific learning style preferences and their use of navigation and design elements of Web interfaces for course-related tasks. Evidence from this study suggests significant improvements in the design of Web interfaces to improve usability and general satisfaction of adult learners. Although these issues have been recognized by previous studies, most of the extant research has either overlooked these particular connections or focused on different areas of importance. The published body of scholarly literature on adult learners, learning styles, Web-based learning, usability and interface design served to inform and support this study.

This study had several purposes:

- to collect baseline quantitative and qualitative data from a sample population of adult students using the Web in a formal, higher education setting to measure the connections between adult student learning preferences and visual design interface elements of educational Web sites;

- to asses the degree and magnitude of correlations between specific learner styles and usage of interface elements of educational Web interfaces;
- to explore the associations of adult student performance and satisfaction with the use of Web tools for course purposes with usability of these tools;
- to see if generalizations for improved design of Web interfaces with improved sensitivity to adult student learning styles can be made for the wider population of adult learners.

The results of this study contribute to the body of literature on adult student use of Web resources. Additionally, the recommendations for improvements in usability design and improved awareness of the importance of adult learning needs represented in visual interface design help to lay the foundation for improvements in developing more effective Web designs for adult learners.

Delimitations and Assumptions of the Study

This study investigated phenomena of a specific population and recommendations, conclusions and generalities based on the specific data of the test population were made in an effort to support the assertions of the research hypotheses. Findings from this research may be limited in scope as to recommendations and generalizations to the larger population of adult learners. Additionally, as this study involves content that falls at the fluid crossroads of several overlapping disciplines, a few important limitations on the scope of this research must be defined. This project investigated the connections between learning preferences of adult learners and their specific use of, and satisfaction with, interface design elements of course-related material delivered via the World Wide Web. However, this investigation did not cover in detail the broader areas of the disciplines of adult education and distance education as well as the general philosophies of teaching and learning. While these are related topics and as a practical matter may overlap considerably with the content of this study, the social, political, and organizational aspects of these broader topics should be understood as beyond the specific focus of this investigation.

As the dissertation committee is aware, within the educational research community there is a long-standing debate over the value and understanding of learning style classifications and theory. This study is written with an understanding of the contentious nature of this topic. Based on the available research, it is my view that there is validity in the use of learning style theory and instruments to aid in the determination of improvements to Web-based adult education research as outlined in this paper. Learning style theory informs this study to the extent that it is integrated into the research and practice of adult and technology based education. In this study, learning styles are generally referred to by the more inclusive term, *learning preferences*, as is the practice in much of the contemporary work on adult learning in the *learning-centered* research tradition (McLoughlin, 1999). This semantic difference represents an attempt to legitimately distance the focused use of learning style theory and instruments in this dissertation from the larger body of writing advocating specific, rigid teaching and learning prescriptions based on an overly close reading of certain aspects of learning and cognitive theory. The use of learning style instruments was employed primarily to aid in clarification of quantitative data as many other researchers have done in recent, well-grounded studies (see Ching-Chun, 1998; Clark & Lyons, 1999; Curry, et. al., 1999; Cushing, 1998; Day, Raven, & Newman, 1998; Digilio, 1998; Felder, 1996; Hu, Reed, & Nelson, 1999; Lucas, 1999; Martinez, 1999; McLoughlin, 1999; Robotham, 1999).

Additionally, within the broader study of educational theory, there is debate as to the general importance and value of technology in education. Again, it is my view that there is value in the use of Web-based computer technology to offer unique advantages to learners, if appropriately implemented. Dillion and Gabbard (1998) reconcile some of the contradiction and confusion evident in the literature concerning pedagogical theory, practical testing and the efficacy of the use of hypermedia in educational settings and found that there is no clear adoption of one learning theory or testing outcome that explicitly denies the value of Web-based hypermedia in education. However, this larger issue touches on the content of this study but should be generally considered outside of its scope.

Chapter II: Review of Literature

The literature surveyed in support of this investigation contextualizes the primary research by presenting overviews of generally accepted theories on the principle areas of inquiry addressed in this study: adult learning, learning preference theory, Web-based learning, Web interface design, human computer interaction, and Web usability.

The literature review search was principally conducted using electronic resources. Initially, the US Department of Education's *AskERIC* database and various Internet search engines including *Google* and *Alta Vista* were used. Keywords used in the search included: *interface design*, *usability*, *learning style*, *adult*, *learning preferences*, *learning style*, *human computer interaction*, *self-efficacy*, and *World Wide Web*. These were searched in various permutations to attempt to account for all combinations. The Proquest Digital Dissertation Web page was also a helpful source for current dissertations in the area of educational technology. As well, searches of the online library catalogs, and subscription databases of several leading research universities were completed using the connection feature of *EndNote* bibliographic software. These included Drexel University, Temple University, The University of Pennsylvania, New York University, Stanford University, The Massachusetts Institute of Technology, The University of Michigan, The University of Wisconsin, and Northwestern University. The descriptors and keywords used in the ERIC search were also used for these searches. The literature review was completed over a two-year period (2000-2002) and the reference searches were periodically (approximately monthly) repeated to verify timeliness and to check for new publications. These references were combined with relevant literature from course work and committee member recommendation.

Table 1 presents an overview of the primary salient points associated with each of the major areas of inquiry covered in this study. The table also lists principal authors and the major ideas affecting the research. This information serves as an advanced organizer and summary of the complete literature review.

Table 1 Principal Authors and Major Points Supporting this Research Study

Area of Inquiry:	Principal Authors and Major Points Relating to Research:
Adult Learning	• **Cross** – Developed Characteristics of Adults as Learners (CAL) model: 1. Adult learning programs should capitalize on the experience of participants. 2. Adult learning programs should adapt to the aging limitations of the participants. 3. Adults should be challenged to move to increasingly advanced stages of personal development. 4. Adults should have as much choice as possible in the availability and organization of learning programs. • **Knowles** – Codified seminal theory of andragogy, the art and science of helping adults learn; including six assumptions: The need to know, The learner's self-concept, The role of the learner's experiences, Readiness to learn, Orientation to learning, Motivation. Knowles' work serves as the foundation of most of the contemporary writing and research on adult learning. • **Tough** – Researched the motivation for greater knowledge, self-esteem, job satisfaction and quality of life of adult learners; suggests that consideration for individual differences (including learning styles) should be taken to improve adult learners' response to formal educational situations. • **Wlodkowski** – Recent additions to adult learning theory focusing on adult learning and motivation; learning process and styles of learning: cognitive, affective, and psychomotor (motivating skills); learning strategies and learning preferences
Learning Preferences	• **Felder** – Developed the Felder / Silverman Inventory of Learning Styles (ILS) that classifies students learning style preferences along four axes allowing for rich dimensional classification. He has done substantial research with university students and Web-based learning tailoring course material to learner's needs resulting in instructional approaches that address a wide range of learner concerns. • **Kolb** – Wrote substantial, founding work on learning preferences theory; Experiential Learning Theory (ELT) explains that students tend to enter a learning situation with a style of learning already developed. If the student meets a learning environment that supports their style, then it is likely the student will embrace the learning environment. • **Gardner** – Multiple intelligence theory often mentioned in discussion of cognitive/learning styles as a pluralized way of understanding intellectual processing, understanding, and mental abilities; identifies seven cognitive faculties, labeled as *intelligences*.

Table 1 continued.

Area of Inquiry:	Principal Authors and Major Points Relating to Research:
Web-based learning	• **Carroll –** Minimalism and technology learning; key principles: 1. Allow learners to start immediately on meaningful tasks; 2. Minimize the amount of reading and other passive forms of training by allowing users to fill in the gaps themselves; 3. Include error recognition and recovery activities in the instruction; 4. Make all learning activities self-contained and independent of sequence. • **Jonassen** – One of the leading writers on constructivist approaches to educational technology; a proponent of technology in education stating that modern information technology can and should support advanced knowledge acquisition and that it can best do that by providing environments and thinking tools that engage constructivistic conceptions of learning. • **Kearsley** – Has written extensively on Web-based learning strategies and technology supported distance education; addresses details of technological concerns. • **Schank** – Proposes five principles for educational technology: learners must understand a task and how it relates to what they are trying to accomplish; systems must offer users appropriate choices at appropriate times; the system must anticipate the informational needs of the learner; learners must understand how choices and information fit into a given task; and learners should feel good about the design of an educational computer system; discusses problem-based learning.
Web interface design and human computer interaction	• **Marchionini** – The individual differences among users as being of primary importance in studying human computer interaction with his research suggesting that differences in abilities, characteristics and experiences users bring to their interaction with a computer system are the most significant factors with the use of the system; he states that systems must have robust interfaces to support wide variety of users. • **Shneiderman** – Has defined models of information navigation; identifies a dynamic query information seeking methodology that has been widely adapted on the Web. Studies of these systems have shown consistently positive results in success and satisfaction rates from both expert and novice users; suggests learners with preferences for graphical and ordinal elements may have greater success and satisfaction with certain search systems. • **Horton**- Theory of Web-based training including searching and information browsing and visual queries. Research on presenting information graphically as an aid to understanding and dissemination and theories on visual queries, browsing and information retrieval. • **Tufte** – Theory of Information Design combining skills from graphic design, technical and non-technical authoring, psychology, communication theory and cultural studies. His guidelines, theories, and examples of effective information displays are helpful for improving information displays and are critically important for designing effective displays of complex data.
Web Usability	• **Card, Moran, and Newell** – GOMS theory of cognitive skills involved in human-computer tasks; model used for interface development and usability testing. • **Nielsen** – Codified basics of Usability Engineering and many standard usability testing methods; five components: ease of learning, efficiency of use, ease of memorization, few errors, and subjectively pleasing. Nielsen’s attribute of subjective satisfaction with Web-based educational material may prove to be the area where there are the strongest connections between student learning preferences and usability. • **Norman** – Advances the concept of unique usability needs for educational Web sites; emphasizes the need to put the user at the center of design initiatives in technology-based learning; calls for a new paradigm for effective design for learning – a learner-centric approach to on-line learning involves an iterative cycle of design-check-redesign working toward a pedagogical usability for e-learning design.

Adult Learners and Learning

The ever-growing body of writing on adult learners and learning focuses primarily on assumptions of adult learners' attitudes and general guidelines and recommendations for adult learning environments. Much of this writing is refined and well grounded in primary research and appropriately views adult learners from situational, demographic, and motivational perspectives (Merriam & Caffarella, 1999). Notably missing from most existing published scholarly work is a succinct and clear working definition of an adult learner. Therefore, it is my assertion that an adult learner could be defined as an individual who meets one or more of the following criteria:

- Defines oneself primarily as something other than just a student (for example, a working professional *and* a part-time student)
- Has taken on grown-up responsibilities at an age when typically one would be primarily focused on schooling (for example, a young, single parent trying to balance parenting, job responsibilities, and schooling)
- Is of a 'non-traditional' age for a college or university student. The National Center for Education Statistics of the U.S. Department of Education (2001) generally categorizes individuals age 25 and over as 'adult' or 'non-traditional' students.

This definition synthesizes some of the ideas of Knowles (1990) and Brookfield (1988) and could be used for defining adult learners for formal education situations.

Also relevant to refining the working definition of the 'Adult Learner' is the perspective of Lifespan Psychology. Within the study of Lifespan Psychology, there are two life stages defined that are most typically associated with adult learning. These life stages, that account for cognitive and psychosocial aspects of education and development are, Early Adulthood (age 20 to 40) and Middle Adulthood (age 40 to 60) (Baltes & Goulet, 1970; Caffarella & Barnett, 1994; Dacey & Travers, 2002; Kail & Cavanaugh, 2000). All of the subjects involved in testing for this study fit into the age ranges defined for these life stages. Additionally, in the context of this study and in many adult and continuing education programs, adult students generally fit a profile defined by the following characteristics. Adult students are:

- often in mid-adulthood and have had work and life experience outside of formal academic settings;
- typically involved in and motivated to further their formal education for specific professional or life goals;
- enrolled in for-credit courses of a degree program at an accredited college or university.

This population of students and their generalizable characteristics should be distinguished from other adult learners at different life stages and in less formal educational settings. While the foundational tenets of adult learning and educational theory may commonly apply to all adult students, the conclusions and recommendations developed through this study should be viewed as having the most relevance to adult students and programs described above. In my view, this is an important distinction that, with further investigation, may prove to be a significant factor in both the motivation and success of adult students interacting with technology and in the design of education programs employing Web-based educational resources; however, this position was not clearly articulated or specifically supported in any of the literature reviewed for this study.

Contemporary understandings of adult learning have developed from theoretical foundations established in the nineteenth century and have been refined, expanded, and codified in recent decades (Knowles, 1990). Most modern writing on adult learning falls into one of five major research areas: self-directed learning, critical reflection, experiential learning, learning to learn, and technology-based or enhanced learning (Brookfield, 1992). Although all of these areas are at least partially linked to this study, this review focuses on only the most relevant points relating to self-directed and technology-based learning. Additional contemporary research in the areas of adult learning preferences, constructivist learning theories, and instructional design methodologies are also relevant and are discussed in this review.

Modern conceptions of the unique needs of the adult learner grew as a reaction to the practice of the prevailing *pedagogical* model and the resultant public education system. Although there are many widely debated individual models of adult learning, the theory of *andragogy*, the art and science of helping adults learn, emerges as the most clearly articulated and widely referenced. Lindeman initially discussed andragogy in the 1920’s as a methodology of adult learning that stressed the improvement of metacognitive skills and group learning. He based some of this theory on Rousseau’s seminal education treatise, *Emile* (see Rousseau & Foxley, 1969), and argued that the gradual accumulation of life experience was the chief difference between learning in adulthood and learning at earlier stages of development. Knowles later formally codified the original andragogical assumptions in the 1970’s. However, the andragogical model is considered incomplete and Knowles qualifies the theory as one that can be integrated with others for developing adult education courses and programs in practice (Cross, 1992; Tough, 1979).

The pedagogical learning and teaching model, which has roots stretching back to the monastic and cathedral schools of medieval Europe, generally assigns responsibility for what, when, and how topics are taught or learned to the instructor. In practice, this paradigm of teacher-directed education leaves the learner in the submissive role of following a teacher’s instructions and has consistently proven to be limiting and unsatisfying for adult learners (Knowles, 1990). Cross (1992) shows as individuals mature, their need to be self-directing, to use their experience, and to identify their personal readiness to learn increases substantially. Traditionally, the public educational system seems to restrict this natural growth and maturation with the continued use of a dependent pedagogical model that results in a gap between adults’ natural need to be self-directed in their learning and their ability to do so in most formal educational settings. This conflict often produces tension and resistance in individual learners (Knowles, 1990).

A philosophical discussion of andragogy’s dispute of basic pedagogical tenets was not well articulated in the literature but should be addressed as it is important that andragogy must not be viewed as discounting the theoretical tradition of pedagogy or Piaget’s founding work of modern, developmental psychology (see Piaget, 1932). The andragogical model is based on assumptions that are different from the practice of the traditional pedagogical model of learning but may be better framed as working within the tradition of educational developmental defined by Piaget that shows learning experiences as facilitating natural development of student self-responsibility and educational progress. Piaget’s explanation of heteronomy and autonomy as the two life-long dimensions of self-will and socialization should include the understanding of a developmental transition from a necessarily teacher-centered, heteronomous stage to a self-directed, adult, autonomous orientation (Piaget, 1932). Knowles believes that the adult learner brings life experiences to learning, incorporating and complementing the cognitive abilities described in adolescent development by Piaget. Therefore, it is my view that andragogy was defined more as a starting point for a specific, practical approach to the unique needs of adult learners in formal educational situations than as an academic debate of the value of the pedagogical tradition. Furthermore, I believe that research findings suggest that technology, when appropriately employed, enrich the adult learner’s experiences in formal educational situations supporting the proposals of andragogy as well as enhancing the pedagogical progression from heteronomy to autonomy.

The key andragogical assumptions are listed as follows and expanded on below:

- The need to know
- The learner’s self-concept
- The role of the learner’s experiences
- Readiness to learn
- Orientation to learning
- Motivation.

Adults need to know why they need to learn something before beginning to learn (Knowles, 1990). Tough (1979) found that adults typically invest considerable energy into discovering the benefits and downfalls to learning or not learning a particular skill or task. Knowles also identified the more difficult issue of the adult learner's self-concept. Adults normally have a self-concept of being responsible for their own decisions but when faced with traditional educational activities they are often in conflict with their conditioning of being a dependent learner in a school situation. This must be overcome by adult education experiences that allow students to make a transition from dependent to self-directed learners. It is also important to consider the role of the learner's experiences. Unlike younger students, adult learners have more experience if simply because they have lived longer. This life experience creates more individualism in a group of adult learners and greater emphasis needs to be placed on individualization of teaching and learning strategies as a result. The implication of this point is that if adults perceive their experience as being rejected due to a lack of individualization in an educational activity, they may also feel they are personally being rejected because their experiences are so much a part of who they are as adults and as learners (Knowles, 1990).

Adult's readiness and orientation to learning are also significant elements of the andragogical model. Adults typically are best at, and most motivated to learn things that they need to know to deal with practical or life situations. This idea dictates an adult orientation to learning that is distinctly different from a child's. Children have a subject-centered orientation mandated by public schooling while adults are life-centered and are motivated to learn how to solve problems or complete tasks that they perceive will help them in their life situations (Tough, 1979).

Motivation is another significant difference between adult and youth learners. Children and youth learners are conditioned to respond to external factors like grades. Adults are responsive to some external motivators in learning, for example job promotions and higher salaries. However, Tough (1979) has found that the strongest motivator for most adults is internal motivation for greater knowledge, self-esteem, job satisfaction and quality of life. This motivation is often blocked in adult education situations by the lack of consideration for the needs of individual adult learners. This point may initially seem somewhat contradictory to the idea of practicality of 'adult's readiness and orientation to learning' but I believe that this is misleading. These ideas function in tandem where motivation should be viewed as a broader concept that informs the practical nature of readiness and orientation to learning. As well, the life stage of an individual adult learner is noteworthy to this discussion as external and internal motivation factors have different significance in different life stages. It is generally understood that practical, external motivation relating to professional success is more prominent in middle adulthood and that internal motivation for self-growth develops as a more significant factor in later adulthood (Tough, 1979).

Since the 1970's additional contemporary learning theories have built on the foundation of andragogical theory and informed the practice of adult education. The more recent work of Cross (1992), Gardner (1985), Kolb (1984), Wlodowski (1990) and others has helped to strengthen and broaden the understanding of adult learner's need to know and self-direction in learning practice (Knowles, 1990). The addition of new developments in cognitive psychology and learning preferences have also contributed significantly to a deeper understanding of the differences of adult learners and the need to embrace these differences for adult education to successfully connect with individual learners. These newer theories have also addressed the unique needs adults have in using technology in educational settings.

Cross (1992) makes perhaps the most substantial recent addition to adult learning theory by building on andragogical thought with her "Characteristics of Adults as Learners (CAL) model." The CAL model integrates the theoretical ideas of adult learning, the experiential learning of Rogers and Freiberg (1994), and lifespan psychology producing a practical framework for adult learning and education. The CAL model consists of two classes of variables: personal characteristics and situational characteristics. Personal characteristics include aging, life phases, and developmental stages. These three dimensions have different impacts on adult learning. Aging results in the deterioration of certain sensory-motor abilities including eyesight, hearing, and reaction time while intelligence abilities including decision-making skills, reasoning, and vocabulary tend to improve. Life phases and developmental stages such as marriage, job changes, and retirement involve a series of plateaus and transitions that may not be directly related to age but have shown to have significant impacts on adult learning. In the CAL model, situational characteristics consist of part-time versus full-time learning, and voluntary versus compulsory learning. According to Cross, the administration of learning such as schedules, locations, and procedures as well as the self-directed, problem-centered nature of most adult learning is strongly affected by these variables.

The CAL model presents a viewpoint for adult learning but is also intended to provide guidelines for adult education programs and includes four key principles toward this end:

- Adult learning programs should capitalize on the experience of participants.
- Adult learning programs should adapt to the aging limitations of the participants.
- Adults should be challenged to move to increasingly advanced stages of personal development.
- Adults should have as much choice as possible in the availability and organization of learning programs (Cross, 1992).

When considering the role of technology in adult learning, adult educators must determine how to respond to technology and exploit it without diminishing the learning experience. Four general approaches to integrating technology into adult learning are currently used:

- technology as curriculum where adults not only learn content through technology but also learn about technology itself;
- technology as a delivery mechanism where technology becomes the means for instructional delivery;
- technology as a complement to instruction where technology is used to complement instruction and extend learning;
- and technology as an instructional tool where technology is integrated into instructional activities.

The World Wide Web and Web-based instruction have begun to be employed in all of these approaches. How technology can be structured to capitalize on the unique characteristics of adult learners must be considered, and like any other instructional tool, technology can enhance adult learning experiences, but it does not promote learning in and of itself. A primary challenge in using technology effectively is trying to understand what adults want in the learning environment when technology is employed (Imel, 1998).

Much of the current academic discussion of adult student use of the Web emphasizes the integration of the Web into traditional face-to-face courses; the same tools and methods can also be applied to distance learning. As adult educators begin using the Web to supplement their traditional courses, they face broad questions about technology, curriculum, construction, and evaluation (King, 1998). Perhaps the primary challenge to adult learners will be the need to refine their analysis and evaluation skills as they traverse the ever-growing world of the Web. These issues of challenges that technology poses to adult learners inform some of the underlying questions in this study and prove to be a significant link with adult student perception of success and satisfaction with Web-based technology.

Learning Success

Another issue that is central to both the study of adult learners and this investigation is the question of a definition of learning ‘success.’ The research literature did not specifically address this question, as most authors seem to rely on a broad, general definition that implies some type of achievement in learning. However, this could be seen as an important concern related both to measurement of learners' interactions with specific educational situations as well as a broader, more philosophical view of enduring learning and cognitive development. For the purposes of this investigation, learning success is viewed as having two dimensions. First, is what might be considered 'procedural success' that encompasses the achievement or failure rate of individual interactions and includes timing and steps taken in attempts to complete a specific assignment. Second, is a developmental view that might be seen as more 'authentic learning success' that reflects positive affects beyond the immediate interaction of the learner with a specific pedagogical situation. While both dimensions are significant, the testing methods of this investigation are focused on the measurable aspects of 'procedural success.' In this study then, 'learning success' is intended to be seen from the perspective of achievement in individual tasks as well as the learner's subjective perception of their experience interacting with the test Web sites. It seems probable that positive experiences and perceptions related to experiences with individual tasks may contribute to overall, lasting learning success although this question is generally outside the scope of this investigation and thus was not specifically addressed in this study.

Learning Preferences

Learning styles and *learning preferences* describe characteristic styles of learning and it is widely accepted (Knowles, 1990; Kolb, 1984; McLoughlin, 1999; Robotham,

1999) that students have different learning styles defined by strengths and preferences in the ways they appropriate and process information. Some students tend to focus on facts, data, and algorithms; others are more comfortable with theories and mathematical models. Some respond strongly to visual forms of information, like diagrams, and schematics; still others prefer verbal forms—written and spoken explanations. Also, it is generally acknowledged that while it is possible to identify common constituent elements, the learning process varies at an individual level (Robotham, 1999). Students will develop a way or style of learning, and refine that style in response to three groups of factors:

- unconscious personal interventions by the learner,
- conscious interventions by the learner,
- and interventions by some other external agent.

The term learning style began to appear in educational research literature in the 1970's and has been adapted into many learning and instructional design theories and models since. The primary reason mentioned for the emergence of the term is that learning style has a practical application in the development of education and training material (Robotham, 1999). Keefe and Ferrell (1990) suggest that the term learning style indicates an interest in the totality of the processes undertaken during learning and define learning style broadly:

> "…a complexus of related characteristics in which the whole is greater than its parts. Learning style is a gestalt combining internal and external operations derived from the individual's neurobiology, personality and development, and reflected in learner behavior" (Keefe & Ferrell, 1990, p. 16).

Learning preference therefore relates to the general tendency towards a particular learning approach displayed by an individual. Curry (1990) suggests there are three different perspectives on learning styles and preferences:

- those relating to a preference for a particular instructional approach
- those relating to the individual's intellectual approach to assimilating information independently of the environment
- and those relating to the individual's intellectual approach to assimilating information with the environment.

Generally, all learners have some strengths, preferences, and weaknesses in modes of understanding educational material. Learning styles can be used to predict what kind of instructional strategies or methods would be most effective for a given individual and learning task; however, research on this question has not identified conclusive relationships. Many learning style frameworks have been applied in university settings and seem to be useful in terms of creating awareness of individual differences in learning (Witkin & Goodenough, 1981). Learning style models that help students build their skills in both their preferred and less preferred modes of learning provide good frameworks for designing instruction with broad breadth (Felder, 1993).

Although it is widespread, research relating to learning styles, and learning preferences is generally undermined by a lack of confidence because researchers in different traditions and contexts have addressed these topics in unique, and often conflicting, ways (Murray-Harvey, 1994). Learning styles and preferences have been studied and debated in two academic research traditions, both of which have impacted the contemporary understanding of these concepts.

The first stream of research on learning preferences and *cognitive styles* is labeled ‘cognitive-perceptual’ and comprises researchers in the field of Psychology (McLoughlin, 1999). Riding and Rayner (1999) summarize much of this work with a categorization of two cognitive style families that relate to how individuals process and represent information and suggests that learners differ in two primary dimensions. The *wholist-analytical* dimension describes how individual process information. Analysts tend to process information into component parts, while wholists prefer to keep a global view of the topic. The wholistic-analytic approach is similar to that proposed by Pask (1976) as *serialism* and *holism*. Serialism is the step-by-step acquisition of material, while wholism is an exploratory approach where information is first understood as a ‘big picture’ or overview and then broken down into smaller chunks. The *verbaliser-imager* dimension describes how individuals represent information during recall. Thus, *verbalisers* tend to present information in words, while *imagers* tend to present information in pictorial form. It is proposed that these dimensions of cognitive style can be effectively applied to the design of instructional materials so that comprehension is facilitated by matching mode of presentation to cognitive style (Riding & Rayner, 1998). The educational research community has generally viewed this cognitive-perceptual learning preference research, as represented most visibly by the work of Dunn and Dunn and their followers, as overly rigid but still valuable in very limited contexts (Riding & Rayner, 1998).

Distinct from the psychological orientation of cognitive-perceptual learning preference research is the ‘learning centered approach’ that has been undertaken by educators addressing the diversity of the environment in which learning takes place, and driven by concerns for meeting individual differences and learning needs (McLoughlin, 1999). In the learning centered approach, focus has shifted from concentrating on testing and the constructs of intelligence and processing of information to an increased interest in learners’ active response to the learning task and to the learning environment. The learning centered tradition has grown out of process-based models of learning including:

- the learning process as a form of experiential learning (Kolb, 1984)
- learners’ orientations to learning (Entwistle 1981; Biggs, 1979)
- and cognitive skills and strategy development (Keefe & Ferrell, 1990).

Learning centered research shows that learners are dynamic and open to adaptation according to the particular context of learning (McLoughlin, 1999). Admittedly, criticism from both educators and psychologists has been voiced about the learning-centered approach on the basis that it represents an uncertain relationship between learning style and cognition and that concepts are sometimes unclearly defined and used loosely (Riding & Rayner, 1998). However, the strength of the learning-centered approach is that it attempts to contextualize the construct of learning preferences and to apply the insights gained to improving pedagogical practice. It has therefore grown in general acceptance among educators in recent years (McLoughlin, 1999; Prosser & Trigwell, 1999) and has been adapted into adult learning theory (Robotham, 1999; McLoughlin, 1999). The learning-centered research served as a general guideline for the use of learning preference-related ideas in this project but is built on with a prescriptive approach to improving the development of Web-based educational resources.

A major premise of research on individual differences among students is that instructors should adapt instruction to accommodate varieties in individual abilities and learning preferences (Jonassen, Mayes, & McAleese, 1994). The principle application of knowledge concerning individual student learning preferences in the area of education is the attempt to match student learning style with instructor teaching method. Some proponents of the use of learning style theory in educational practice state that if one were able to diagnose the learning style of an individual, then it would seem logical to assume that matching the characteristics of instruction to that style would make the instruction more effective. Students tend to enter a learning situation with a style of learning already developed. If the student meets a learning environment that supports their style, then it is likely the student will embrace the learning environment (Kolb, 1984). Norman (1994) supports this asserting that cognition has two modes, the experiential and the reflective, and the challenge in the design of computer-based learning environments is to maximize the optimal use of both of these modes of cognition.

The terms, *cognitive styles* and *learning styles*, are often used to describe the same psychological phenomenon; however, there is disagreement about the differences and scope of these ideas. According to the cognitive-perceptual tradition, cognitive style refers to the preferred way an individual acquires and processes information and is thought to refer to an individual's more stable psychological traits (Dunn & Dunn, 1999).

For the purposes of this investigation, a broader, inclusive definition of the ideas of learning and cognitive styles was adapted. The general implications for learning are that educational material should be designed to be sensitive to multi-sensory preferences. Gardner’s (1985) multiple intelligence theory also is often mentioned in discussion of cognitive styles as a pluralized way of understanding intellectual processing, understanding, and mental abilities. Gardner identifies seven cognitive faculties, which he labels as *intelligences*: musical intelligence; bodily-kinesthetic intelligence; logical-mathematical intelligence; linguistic intelligence; spatial intelligence; interpersonal intelligence; intrapersonal intelligence. But, unlike individual differences in abilities as represented by Gardner’s model, which describe performance, cognitive styles describe a learner’s typical mode of thinking.

There is further dispute over the acceptance for any one theory for determining individual learning differences and the consistency of personal learning styles (Robotham, 1999). This debate has little significance for this research study on adult, self-directed, technology-enhanced learning as adult learning theory, as researched by Felder (1996), Kolb (1994), Norman (1999), Cross (1992), and Knowles (1990), has consistently shown adult learners to be established in their learning style preferences. It has also been suggested that the research underlying some of the work into learning style is flawed particularly relating to the areas of the nature of learning tasks in relation to the dichotomies of learning styles (Hayes & Allinson, 1996). This is seen as important to many educators as it has implications for whether one should attempt to match learning style to instructional style (Robotham, 1999). Although recent research (see Ching-Chun, 1998; Clark & Lyons, 1999; Curry, et. al., 1999; Cushing, 1998; Day, Raven, & Newman, 1998; Digilio, 1998; Felder, 1996; Hu, Reed, & Nelson, 1999; Lucas, 1999; Martinez, 1999; McLoughlin, 1999; Robotham, 1999) has shown strong evidence to support the matching of instructional material with existing student learning strengths, discussion continues over the exact implementation of these ideas. Some research does indicate that students, regardless of learning style, sometimes perform equally well on tests of cognitive tasks, although they may acquire information in different ways in a hypermedia-learning environment (Weller, et. al., 1995). Additionally, some researchers feel that, to be considered valid, the learning style of an individual would need to be consistent over time. Research by Cornett (1983), and Pinto et. al. (1994) has shown that while there may be slight variations in the learning style of an individual adult student as reported on testing instruments the essence of that style will typically remain unchanged over time.

There are many learning style models and instruments with varying perspectives of emphasis. Learning style models have proven to be useful if balancing instruction on each of the model dimensions meets the learning needs of most students in a given population. Felder (1996) believes that the learning style model and instrument used is secondary to the process of tailoring course material to learner’s needs as long as the resulting instructional approaches address a wide range of learner concerns. Generally, the research has shown that learning style theory and instruments can be equally valuable to educators designing a traditional course or developing Web-based instruction (Felder, 1996). All of the popular learning style models share similar traits of classifying learners in several categories and suggesting that the results taken from the models should be used to make general assumptions about the test subjects and related instructional approaches (Knowles, 1990). A student's learning style profile developed from scores on a learning style instrument provides an indication of probable strengths and possible tendencies or habits that might lead to difficulty in academic settings; the profile does not reflect a student's suitability or unsuitability for a particular subject, discipline, or profession (Felder, 1996).

The Felder / Silverman and Kolb instruments were used for this study as they have the richest variation in dimensions and have both been validated in recent studies involving instructional technology.

Kolb's (1984) Experiential Learning Theory (ELT) hypothesizes that learning follows four specific and consecutive states: concrete experiences (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE). The CE/AC and AE/RO dimensions are polar opposites as far as learning styles are concerned and Kolb postulates four types of learners (divergers, assimilators, convergers, and accommodators) depending upon their position on these two dimensions. Kolb's model is actually two models in one that includes a four step learning process: Watching [introvert – reflection], Thinking [mind], Feeling [emotion], Doing [extrovert – muscle], and a description of the four learning styles used within the learning process: Reflectors, Theorists, Pragmatists, and Activists (see Figure 1).

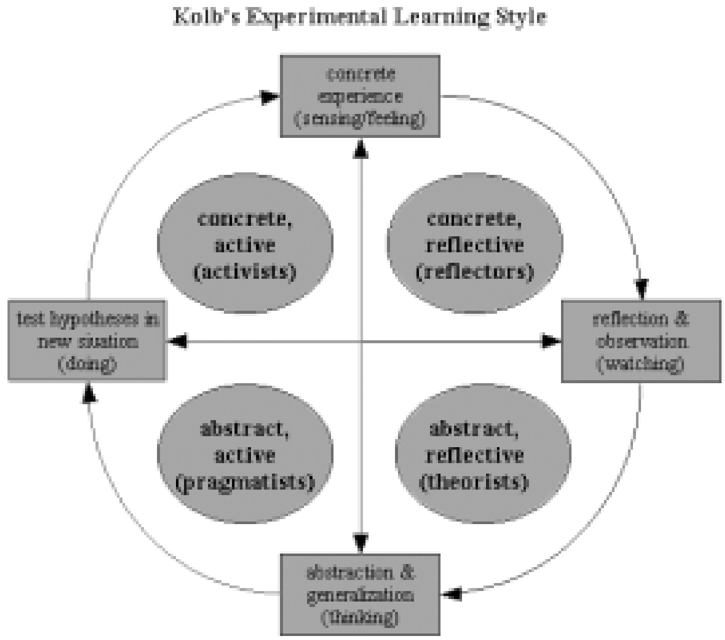

Figure 1 Kolb Learning Style Model

The four types of learners in the Kolb classification scheme are:

- *Type 1* - Watcher (concrete, reflective). A characteristic question of this learning type is *Why?* Type 1 learners respond well to explanations of how course material relates to their experience, their interests, and their future careers.
- *Type 2* - Thinker (abstract, reflective). A characteristic question of this learning type is *What?* Type 2 learners respond to information presented in an organized, logical fashion and benefit if they have time for reflection.
- *Type 3* - Feeler (abstract, active). A characteristic question of this learning type is *How?* Type 3 learners respond to having opportunities to work actively on well-

defined tasks and to learn by trial-and-error in an environment that allows them to fail safely.

- *Type 4* - Doer (concrete, active). A characteristic question of this learning type is *What if?* Type 4 learners like applying course material in new situations to solve real problems.

Studies using the Kolb model in graduate education suggest that teaching students about learning styles helps them learn the course material because they become aware of their thinking processes (Kolb, 1984). A pioneering program at Brigham Young University using the Kolb model helped faculty members successfully redesign their Web-enhanced courses in an attempt to reach the full spectrum of learning styles by using a variety of methods such as group problem solving, brainstorming activities, design projects, and writing exercises in addition to formal lecturing (Felder, 1996).

A similar model with a practical orientation toward technology-enhanced education is The Felder / Silverman Inventory of Learning Styles (ILS) developed at North Carolina State University. The Felder / Silverman model classifies students along four dimensions as:

- *sensing learners* (concrete, practical, oriented toward facts and procedures) or *intuitive learners* (conceptual, innovative, oriented toward theories and meanings);
- *visual learners* (prefer visual representations of presented material—pictures, diagrams, flow charts) *or verbal learners* (prefer written and spoken explanations);

- *active learners* (learn by trying things out, working with others) or *reflective learners* (learn by thinking things through, working alone);
- *sequential learners* (linear, orderly, learn in small incremental steps) or *global learners* (holistic, systems thinkers, learn in large leaps).

Using the Felder / Silverman model, a hypermedia package for a computer science course on information systems has been developed for the Web. Every lesson starts with a list of objectives and is followed by several different presentations of the lesson material, each geared toward a different learning style. The hypermedia package allows students to assess their learning styles using an online version of the Felder / Silverman instrument and the Web interface then provides them the option of having the material presented in a manner tailored to their style preferences, structuring the lesson so that the preferred media elements come first. Students who prefer to organize the presentations themselves without following a particular sequence may do so as well (Felder, 1996). Some suggestions for Web-based course design have already been developed from studies using the Felder / Silverman learning style model. The following are representative examples:

- Teach theoretical material by first presenting phenomena and problems that relate to the theory (sensing, inductive, global).
- Balance conceptual information (intuitive) with concrete information (sensing). Intuitors favor conceptual information—theories, mathematical models, and material that emphasizes fundamental understanding. Sensors prefer concrete

information such as descriptions of physical phenomena, results from real and simulated experiments, demonstrations, and problem-solving algorithms.

- Make extensive use of sketches, plots, schematics, vector diagrams, computer graphics, and physical demonstrations (visual) in addition to oral and written explanations and derivations (verbal) in lectures and readings.
- To illustrate an abstract concept or problem-solving algorithm, use at least one numerical example (sensing) to supplement the usual algebraic example (intuitive).
- Use physical analogies and demonstrations to illustrate the magnitudes of calculated quantities (sensing, global).
- Demonstrate the logical flow of individual course topics (sequential), but also point out connections between the current material and other relevant material in the same course, in other courses in the same discipline, in other disciplines, and in everyday experience (global).

Although research supporting learning styles with adult learners has had mixed results, theories and instruments are worthwhile tools if properly administered and tested particularly as the phenomena related to learning preferences is regularly observed by researchers and practitioners (Knowles, 1990). The most consistent success with learning preference theories and learning style instruments thus far has been in three areas:

- to create awareness among educators that learners have differences
- as starting points for learners to explore their preferences
- and as catalysts for discussions about best learning strategies and practices.

Additionally, there has been some success with learning style instruments in tests and implementations of specific learning groups with finite learning goals as in this investigation (Knowles, 1990).

Computer Self-Efficacy

As computers have become more prevalent in educational settings, and the offerings to the user more sophisticated and more complex, self-efficacy has become an important and closely studied phenomenon. Self-efficacy research has particular significance to this study as it is directly related to developments in human-computer interaction and interface design. Although most educational computer interfaces are becoming increasingly intuitive, studies suggest that for the inexperienced user computer interaction can still pose formidable challenges (Compeau & Higgins, 1995). For many, the ability to benefit from computer technology in educational settings is limited by an inability to understand or control the technology. This inability may be real, in that the individual genuinely may not have the necessary skills or abilities, or it may simply be a belief, which results in incapacity and poor motivation as in the case of self-efficacy expectations (Eachus & Cassidy, 1997).

The construct of self-efficacy has emerged as a central facet of Bandura’s social cognitive theory and has been refined and applied to educational settings consistently since the 1970’s. Self-efficacy can be defined as the beliefs an individual has about their capabilities to successfully perform a particular behavior or task. Bandura proposed the self-efficacy model as a paradigm of personal expectations derived from four principal sources of information: performance accomplishments, vicarious experience, verbal persuasion, and physiological states (Bandura, 1986). Levels of self-efficacy are thought to be determined by the following factors: previous experience (success and failure); vicarious experience (observing others' successes and failures); verbal persuasion from peers, colleagues, relatives; and affective state (emotional arousal such as anxiety) (Bandura, 1986). Over the past few decades, ideas relating to self-efficacy have proven to be central elements in the understanding of success and motivation in many academic settings and situations. The nature of self-efficacy as an egocentric construct demands that it be measured directly rather than indirectly and is therefore calculated using self-report scales on self-efficacy instruments (Eachus & Cassidy, 1997).

The increasing reliance in higher education on computer technology to facilitate student learning and the effects of self-efficacy beliefs on students' motivation to exploit the intuitive nature of the human computer interface suggests the value of using computer self-efficacy instruments to evaluate student use of educational technology (Eachus & Cassidy, 1997). Specific success has been demonstrated where instruments have been used to identify students with low self-efficacy beliefs within the computer domain. This could be important to student development as low self-efficacy beliefs may prove an immediate as well as a long-term obstacle to academic success and progress because students may remain poorly motivated and perceive themselves as having little personal control over their learning environment (Eachus & Cassidy, 1997).

Compeau and Higgins (1995), in their seminal study, tested several hypotheses related to a hypothetical linear model of computer use based on social cognitive theory. Their results suggested that individuals with high self-efficacy used computers more, enjoyed using them more and experienced less computer-related anxiety. The importance of self-efficacy in explaining computer use has been demonstrated in a growing number of recent studies as well (see Abu-Jaber, & Qutami, 1998; Chou, 2000; Eachus & Cassidy, 1997; Yi, & Venkatesh, 1996). Eachus, and Cassidy (1997) found that computer experience has also been associated with determining levels of computer self-efficacy. They showed that although positive computer experience increased computer self-efficacy, the actual amount of experience (i.e. time on task) was not correlated with self-efficacy beliefs of university students in their experiments. Thus they suggest that it is the quality not the quantity of experience that is a critical factor in determining self-efficacy beliefs related to computer use in educational situations. Also, their research suggests that computer self-efficacy beliefs are associated to a significant extent with success or failure in experiential learning including computer-facilitated training and teaching (Eachus & Cassidy, 1997). Similarly, Hill and Hannafin (1997) report on a study of searching strategies used by adult learners on the Web finding that: learners use a variety of strategies; self-reported knowledge appears to affect the strategies used; and perceptions of disorientation and perceived self-efficacy influence the strategies used.

Dejoy and Mills (1989) focus the significance of self-efficacy more closely to this research study by relating the importance of self-efficacy to motivating factors of adult self-directed learning and learner control of technology resources. They identify critical features of learner control for adult students, including: the opportunity to practice new learning immediately; regular feedback on performance; adjustable levels of difficulty; adjustable pace of presentation; control over the sequence of information presentation; opportunity to review, correct, or repeat information; opportunity to enter, exit, and re-enter the program without repetition; and the opportunity to save responses for future use. In their research, they have seen improvements in adult learning and self-efficacy through increases in learner control of adult education situations and technology (Dejoy & Mills, 1989).

Web-based Learning and Instructional Design

In just the past few years, the Word Wide Web and the Internet have grown to have a major presence in school, university and business educational settings and have been praised by educators as a vehicle for promoting lifelong learning and broadening the numbers and diversity of adults participating in education. The impact of the Internet on formal adult education should be considered substantial at least in terms of the numbers of learners involved as roughly fifty percent of the students enrolled in college are now older than age 25 (Donaldson & Graham, 1999). More than a million people in the United States were registered in online courses for credit during the 2000-2001 academic year. This number grows every year and does not include the many adult learners who enrolled in noncredit courses or students who use Web-based resources to augment a face-to-face class (Harmon, 2001). Whether the Web is used as an educational tool to enhance a traditional classroom, or as the primary delivery medium for Web-based synchronous or asynchronous distance learning, it can be used in many ways in courses, ranging from the simple to the complex (Cyrs, 1997; Driscoll, 1998). A widespread pattern has developed over the past several years where instructors begin by using the Web to supplement their courses in basic ways, gradually exploring more complex uses of Web technology. The simplicity and flexibility of the Web make it possible for many teachers and trainers to accomplish a great deal, regardless of their prior level of technical skill (King, 1998). In terms of its possibility for course enrichment, the most frequent arguments in favor of Web-based instruction are its ability to reach students and offer flexibility. The practice of providing live instruction on the Web that can be accessed by students later for study and review also has great potential, and using the Web to access current resources is cited as one of the greatest advantages of the Web for instruction (Altekruse & Brew, 2000).

Although use of the Web has shown to be beneficial in many learning environments, it is worthwhile to organize the types of Web-enhanced learning resources for purposes of analysis. No widely accepted, readily available, formal taxonomy of Web-based educational resources has been defined, so I have developed the following basic framework for classification and organization of the different uses and types of Web-based learning material:

- synchronous on-line distance learning courses
- asynchronous on-line distance learning courses

- self-paced, Web-based learning or training modules
- on-line resources that support or augment a traditional classroom-based course
- and on-line research databases, information services, or data-mines.

Examples of all but the ‘synchronous on-line course’ were used in this research study. It is my view that there currently is a lack of a clear categorization and understanding of the different types of Web-based educational resources and that this basic organization scheme is important to the general understanding of the capabilities of the technology. A broader adaptation of this would be helpful if implemented in the larger research community by aiding in refining both the commonalities of these resources and the unique goals and restraints associated with the particular uses of each of the educational Web site groupings.

Comprising much of the current literature covering both distance-based and in-class use of the Web is research on instructional design models and educational requirements for Web-based learning. A notable problem in the existing research is the nearly ubiquitous use of a variety of often confusing and conflicting terms relating to Web-based learning. Web-based Instruction (WBI), Web-based Training (WBT), Web-based Teaching, On-line Learning, On-line Training, E-Learning and many similar terms are used by different authors to label essentially the same idea of an academic or professional course delivered either in part or completely over the World Wide Web. It is my view that the subtleties of the differences in these definitions is not essential to their use or understanding and therefore for this research these terms should be understood as synonymous and used interchangeably. The one exception to this might be the distinction between Web-based learning as administered by colleges and universities and Web-based training offered by corporations and training centers (Driscoll, 1998). In this case, the nomenclature may help to explain the purposes of the learning material but the concerns for adult learners needs and the value of visual and instructional design would be similarly important.

Formal instructional design models make up a large portion of the literature informing the design of Web-based educational resources and represent a myriad of overlapping approaches to course and learning material development. Overall, instructional design models are more focused and prescriptive than the broader, more descriptive educational theories on which they are based. Most of the basic tenets of instructional design theory are rooted in the work of Bruner but are not uniformly adapted into contemporary models. Bruner (1966) proposes that any theory of instruction should address four major features of the learning material and learner's attitudes:

- the individual's predisposition towards learning,
- the ways in which a domain of knowledge can be structured so that it can be most readily comprehended by the learner,
- the most effective sequence in which to present material,
- and the nature of rewards and punishments for success with learning material.

In Bruner's view, effective methods of instructional design are driven by structuring knowledge that should result in simplifying, increasing the manipulation of information, and generating new propositions (Kearsley, 2000).

Dick and Carey (1996) present one of the best known and widely adapted models using a systems approach for designing instruction that is similar to the methodology of software engineering. Their *systems approach design model* describes the phases of an iterative process for developing learning materials and activities that includes analysis, design, development, implementation, and evaluation and is founded in the idea that the effectiveness of any instruction is predicated upon the structure of the instructional elements. This model has proven to be applicable across a range of context areas including higher education and business settings and can be applied to novice and expert learners.

The *situated learning* instructional design model is also frequently referenced in current writing. Proposed by Lave, situated learning is a theory of knowledge acquisition that has been applied in the context of technology-based learning activities and used in experiments involving artificial intelligence. Lave argues that learning is a function of the activity, context and culture in which it arises (Lave & Wenger, 1990). The situated learning theory suggests that knowledge needs to be presented in an authentic context, and that learning requires social interaction and collaboration. Situated learning builds on the work of Vygotsky and has been expanded by other theorists to emphasize the need for a new epistemology for learning one that emphasizes active perception over concepts and representation (Kearsley, 2000).

Constructivism is the most substantial and influential theoretical paradigm presented in connection with improving the design of Web-based educational resources. Constructivism is broad-based and grounded in the fields of philosophy, psychology and sociology and should be understood as having far-reaching influence in many diverse academic disciplines. Constructivist learning is based on students' active participation in problem-solving and critical thinking regarding a learning activity and is rooted in the seminal writings of Bruner, Piaget, Vygotsky and Dewey. Savery and Duffy (1995) summarize the major principles of the constructivist paradigm:

- Knowing and understanding occur during interactions with the environment. Understanding is a function of the content, the context, the activity of the learner, and perhaps most importantly, the goals of the learner.
- A "cognitive conflict or puzzlement" stimulates learning and the organization and nature of what is learned. The learner's goal is central to what is learned.
- Knowledge and understanding occur through social negotiation and through the evaluation of the viability of individual understandings.
- Understanding or knowledge is formulated by testing through interactions with others. Group collaboration, either in person or in electronic discussion, provides a mechanism for determining better understanding.

Squires (1999) presents a viewpoint representative of many writing on constructivism and software and Web development. He expresses the hope that taking a constructivist approach to software design will lead to better educational software and better learning but concedes that the potential synergy between multimedia environments and a constructivist educational approach could lead to new challenges and complexities for educational software development. His work focuses on how educational software, and interfaces in particular, can be designed to reflect a constructivist approach. Squires states that:

> "…personal construction of knowledge and recognition of the importance of context has far reaching consequences for the use of educational software. Learners will perceive the function of software and interpret its behavior in idiosyncratic ways, depending on the way in which they construct knowledge and they relate to contextual factors. An educational software package should not then be seen as a fixed entity defined by the designer, but rather as a personal construct in the mind of the learner (Squires, 1999, p. 50)."

Thus, Squires argues that the overriding design rationale changes from one of strict pedagogic prescription to one of providing rich cognitive experiences informed by theoretical models. From his discussion of constructivism, Squires recognizes that users often fit the use of technology-based environments into contextually tuned, situated learning environments. In this sense, he considers good design to be design which changes with contextual use; this idea supports the investigation hypotheses that there is a direct connection between the visual interface and learner achievement.

Jonassen (1994) presents an in-depth discussion of constructivist roles of technology in education stating that modern information technology can and should support advanced knowledge acquisition and that it can best do that by providing environments and thinking tools that engage constructivistic conceptions of learning. He believes that this should be accomplished through the use of open learning environments. Open learning systems include the following characteristics:

- need driven,
- learner-initiated interaction,

- and conceptually and intellectually engaging.

Traditional computer-based learning environments are often driven by directive programs that allow the learner to input information; however, the responses to that input are prescribed and predetermined. In open systems, such as the Web, the goals of the system, its uses, activities and options are determined both by sources internal and external to the system.

Jonassen (1994) continues by stating that technology-based learning environments should fulfill an information or knowledge construction need of the learner. If the learner is seeking information to solve a problem or build a better understanding, then constructivistic environments, such as hypertext retrieval systems, should support that need and engage the learner. They state that technology-based environments can also support knowledge construction by providing thinking tools or cognitive learning tools. They define thinking tools as technology systems or applications that extend the intellectual functionality of the learner, and should represent multiple realities. They also note that many knowledge domains are ill-structured, containing few general rules or principles for class inclusion and few defining characteristics making it more difficult to develop technology-based educational solutions that support the author's tenets.

Reisman's *Heuristic Diagnostic Learning* model presents a practical approach to learner-centered instruction and learning that is firmly grounded in the constructivist paradigm. While not specifically focused on Web-based technology, this model can be seen as having significant potential to inform the practice and implementation of Web-based educational environments and is relevant for this investigation as it supports the assertion of a direct connection between preferred learning style and content and delivery of instructional material. Heuristic diagnostic teaching is a process whereby an individual's learning preferences, academic strengths and weaknesses, and prior learning are taken into account to aid in the improvement of one's performance. Heuristic diagnostic teaching and learning are an interactive meld of learner characteristics, content knowledge and pedagogy knowledge that involves the following:

- recognizing generic learner characteristics or influences on learning including learning preferences or styles,
- having in-depth command of the content to be taught,
- assessing where students' learning gaps occur and
- using a repertoire of instructional strategies appropriate to the learner's characteristics and the content to be taught (Reisman, 1998).

Lebow (1993) contributes to the discussion of the compatibility of constructivism and instructional design, proposing "Five Principles toward a New Mindset" of constructivist values that influence instructional design. These principles also support the use of opportunities for learners to engage in distance learning experiences as a means of challenging students to construct their own meaning with the help of others. The principles are as follows:

1. Maintain a buffer between the learner and the potentially damaging effects of instructional practices, including: increasing emphasis on the affective domain of learning; make instruction personally relevant to the learner; help learners develop skills, attitudes, and beliefs that support self-regulation of the learning

process; and balance the tendency to control the learning situation with a desire to promote personal autonomy.

2. Provide a context for learning that supports both autonomy and relatedness.
3. Embed the reasons for learning into the learning activity itself.
4. Support self-regulated learning through promoting skills and attitudes that enable the learner to assume increasing responsibility for the developmental restructuring process.
5. Strengthen the learner’s tendency to engage in intentional learning processes, especially by encouraging the strategic exploration of errors.

Dillion and Gabbard (1998) offer the most comprehensive meta-analysis of current research on educational requirements for Web-based educational software, focusing on the measured effects of hypermedia usage on learning outcomes. Their research covers three themes: studies of learner comprehension compared across hypermedia and other media; effects on learner outcomes based on design changes in hypermedia environments; and individual differences in learner responses to hypermedia. The following are key points from their review of dozens of previous studies:

- hypermedia affords the most advantages for users in specific tasks that require rapid searching through multiple information sources;
- increased learner control over access is differentially useful to learners according to their abilities;

- the interaction of learner style in the use of various hypermedia features offers an explanation of the variety of success different learners have with hypermedia technology.

Dillion and Gabbard also generally conclude that designers of hypermedia learning environments would have to make concessions in creating systems that both have good usability and promote creative exploration of the learning material for a variety of learning types. This investigation attempts to quantify these connections and make general recommendations for an approach to interface design that balances these concerns. Houser and Deloach (1998) also present findings that highlight the ideas that users of educational software should be able to learn how to begin using the application quickly and with minimal effort, and that learners should be aware of how effectively their actions are helping them achieve their goals at all times.

Other researchers have synthesized some theoretical concerns with the practical questions of differences between open and closed computer systems and the limitations of technology used on the Web. Borges, Morales and Rodriguez (1998) found measurable differences in the effectiveness of interactivity in Web-based, open systems and CD-ROM closed systems when used by university students. Based on their observation of student use of Internet and CD-ROM research sources, they made recommendations on the specific sizes of screen interface elements, the organization of site navigation and the type of search engine technology concluding that closed systems often outweigh Web-based systems in usability and performance but that Web systems offered more variety and customization options to suit different user preferences. Evans and Edwards (1999) also found differences in learning styles and comprehension between navigation in open and closed educational multimedia and hypermedia systems. Jacobson (1994) attempts to relate hypermedia use to educational theory in the formation of cognitive structures in a schema-theoretic manner. His theoretical representation is enunciated as an *epistemic beliefs and preferences model* that examines the role of hypermedia in the learning of complex, cross-referenced knowledge; however, Jacobson's argument is somewhat limited, as it does not directly address practical concerns of implementing real systems.

Building on constructivism in a distinctly practical direction is Carroll's minimalist theory (1990; 1998; 2000). *Minimalism* is a contemporary framework for the design of instruction especially training materials for computer users. Carroll (1990) readily acknowledges a theoretical debt of minimalism to the founding work of Piaget but he also states that training developed on the basis of other instructional theories is often too passive and fails to exploit the prior knowledge of the learner or use errors as learning opportunities. The critical idea of minimalist theory is to minimize the extent to which instructional materials obstruct learning and focus the design on activities that support learner-directed activity and accomplishment. Essential to the understanding of minimalist training theory and to the connection with this study is Carroll's criticism of systematic instructional materials. In this, he presents persuasive evidence that user's learning styles, learning strategies and mental models of computer-based tasks are typically not considered or supported by the design of computer training material resulting in frustrated users and ineffective learning. Minimalist theory was developed from studies of individuals attempting to learn a diverse range of computer applications including word processing, databases, and programming and has been extensively applied to the design of computer interfaces and documentation. Minimalism includes the following key points:

- all learning tasks should be meaningful and self-contained activities;
- learners should be given realistic projects as quickly as possible;
- instruction should permit self-directed reasoning and improvising by increasing the number of active learning activities;
- training materials and activities should provide for error recognition and recovery;
- minimize the amount of reading and other passive forms of training by allowing users to fill in the gaps themselves;
- make all learning activities self-contained and independent of sequence.
- there should be a close linkage between the training and actual system.

Minimalist theory relates to andragogical theory as well by emphasizing the necessity to build on the learner's experience. Carroll states:

> "Adult learners are not blank slates; they don't have funnels in their heads; they have little patience for being treated as "don't knows"... New users are always learning computer methods in the context of specific preexisting goals and expectations" (Carroll, 1990, p. 11).

Minimalism also serves as the most direct connection between educational theory and the value of usability with its user-centered focus on optimizing support for observed user performance in work or learning tasks.

Also relevant to the discussion of realistic applications of constructivist theory is the A.C.T.I.O.N. model. With this, Bates (1995) presents a model for selecting media for instruction and learning specifically aimed at professionals and decision-makers in the training and education field who are developing technology-based programs. According to Bates, media selection should be based on answers to the following guiding questions:

- How accessible is the technology?
- How flexible is it?
- How cost-effective is it?
- What kind of learning will be taking place?
- Does the technology support this type of learning?
- What kind of interaction will there be?
- How can this technology be used successfully?
- How quickly can the course be accessed or delivered to the learner?
- How quickly can material be obtained or changed?
- How quickly will the learner see their results?

Working outside of the constructivist paradigm is Gagne's (Gagne, Briggs, & Wager, 1992) *Conditions for Learning* model. This theory is relevant as it suggests that learning tasks for intellectual skills can be organized in a hierarchy according to complexity: stimulus recognition, response generation, procedure following, use of terminology, discriminations, concept formation, rule application, and problem solving. Although there is criticism of this approach, it is often referenced in connection with the development of instructional technology applications particularly Web-based instruction as the hierarchical structure can be mirrored in the design of a multi-level Web-based hypertext system. The primary significance of the hierarchy is to identify prerequisites that should be completed to facilitate learning at each level. Doing a task analysis of a learning or training task identifies prerequisites. In the conditions for learning model, learning hierarchies provide a basis for the sequencing of instruction. In addition, Gagne's theory outlines nine key instructional events and corresponding cognitive processes that serve as a foundation for developing instructional material:

(1) gaining attention (reception)

(2) informing learners of the objective (expectancy)

(3) stimulating recall of prior learning (retrieval)

(4) presenting the stimulus (selective perception)

(5) providing learning guidance (semantic encoding)

(6) eliciting performance (responding)

(7) providing feedback (reinforcement)

(8) assessing performance (retrieval)

(9) enhancing retention and transfer (generalization).

Hypertext and Human Computer Interaction

The Web is a vast collection of interconnected documents based on the concept of hypertext. Conklin (1987) explains hypertext systems as collections of frames of text, pictures, and multi-media elements that are organized in non-linear networks of linked modules (see Figure 2). Hypertext systems can be navigated by associating screen elements with objects stored in a database, or on a Web server, through *links*. Different types of pointers and links can be identified and serve different purposes for the system and user. For example, *keyword links* enable navigation between an index and information nodes through the use of on-screen keywords and implicit linking; as well, *referential links* allow navigation between related information nodes by directly linking two points in the hypertext system (Conklin, 1987). The advantage of the non-linear design of hypertext is the ability to organize, view and navigate information stored in the system in different ways depending on the perspective of the system user (Conklin, 1987). Marchionini and Shneiderman (1988) suggest that hypertext usage depends substantially on the mental models users have for the system which in turn rely on the conceptual models used by the interface designers to create and implement a system. Jonassen considers hypertext-based systems among the best examples of constructivistic learning environments because acquiring knowledge from hypertext requires learners to engage in constructivistic learning processes (Jonassen, Mayes, and McAleese, 1994). Learning from hypertext is task driven and depends largely on the purpose for using the hypertext, which in turn drives the level of processing. Hypertext has generally proven most valuable in enabling human users access to large and complex stores of data.

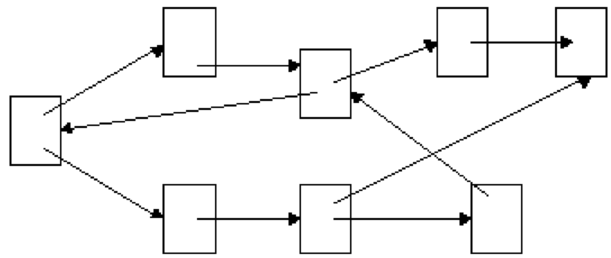

Figure 2 Hypertext

Conklin (1987) qualifies this discussion somewhat suggesting that the two primary challenges to users of hypertext that may ultimately limit its usefulness are *disorientation* and *cognitive overload*. Disorientation is the tendency to lose one’s sense of location and direction in a non-linear document or environment and cognitive overload is defined as the extreme effort and concentration necessary to maintain several tasks or navigation trails at a single time. Hypertext offers a greater degree of freedom, compared to traditional linear text documents, and hence a greater potential for the user to become lost or misdirected. Problems of disorientation and cognitive overload stem from the innate unfamiliarity of the hypertext structure and the challenges associated with organizing the structure (Conklin, 1987; Anderson, 1983). As well, in the practice of Web design, there are several recurring navigation pathologies that stem from a basic mismatch between the physical organization of hypertext and a user's perception of it as viewed through a page-centered Web browser. According to Nielsen (1995), the true purpose of hypertext is to provide open, exploratory information space to the user. Hypertext is designed to support information-seeking navigation through the inclusion of links and nodes; browsing has shown to be an effective way of negotiating implicit goals in hypertext information (Nielsen, 1995). A variety of approaches have been taken to measuring navigational patterns in hypermedia software that include both quantitative and qualitative techniques for collecting and analyzing user interaction data. However, the literature does not reveal any standard measures of navigational patterns, especially such procedures whose reliability and validity have been well established (Horney, 1993). Thus, for the purposes of this study, navigational patterns were measured through test administrator observation and subjective comments from test subjects.

The psychological, sociological, and communication theory elements of the study of human computer interaction (HCI) affect interface design of software and help to contextualize the study of the design of education-related Web sites in this research study. HCI has two principal dimensions. First, HCI serves as a practical framework and methodology that involves user testing during the development of new computer systems. Second, HCI presents an evaluative approach about cognitive and behavioral factors of humans interacting with computers; these two aspects of HCI are interdependent and interrelated (Head, 1999). The primary components of HCI include a *User* interacting with a *System* through a *Task* in a specific *Environment* and HCI research advocates building and evaluating user-centered computer systems based on supportable tasks. The following five questions serve as standard guidelines for HCI evaluation and development of computer systems:

- How will design work get done during the development phase?
- How can systems be designed that work better to support user's tasks?

- What are the design trade-offs and what are solutions that support users?
- What can we make that is new?
- Is the system usable?

As well, the following performance factors are elemental to understanding the user-centered approach of HCI: memory (short and long term), mental models, motivation, perception, reaction time, fatigue, and preferences/inclinations (Preece, et. al., 1994).

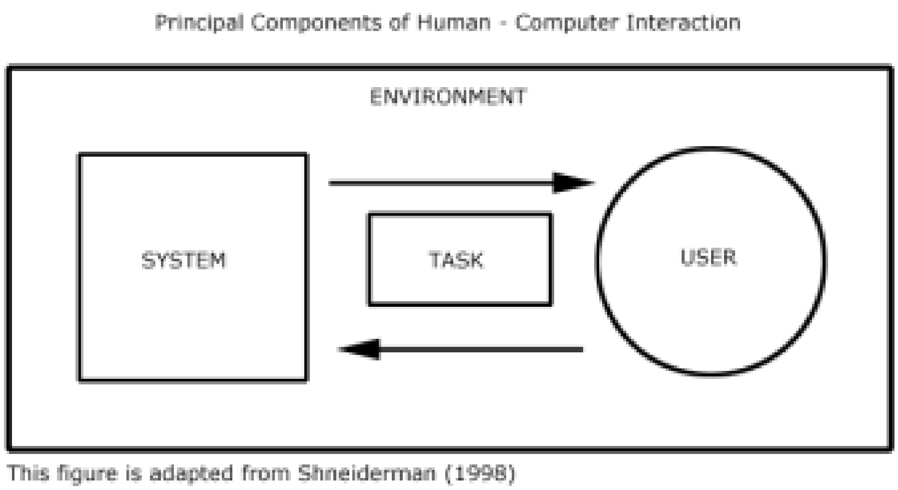

Figure 3 Principal Components of HCI

Cognitive psychology has had a significant influence on HCI research and practice in the following three main areas:

- the study of human information processing;
- language, communication, and interaction;

- and ergonomics.

Techniques and approaches from cognitive psychology help to explain how humans process information, structure actions, communicate with each other and artifacts, and they help to analyze the physical and psychological requirements of the built environment. Cognitive psychology also emphasizes the information processing approach to the study of human behavior and the application of the data and methodologies to problems investigating the role of perception and memory in the comprehension of language. In HCI research, cognitive information dispensation is typically organized into the following 10 processes: recognize, recall, match pattern, compute, apply, analyze, synthesize, evaluate, and create. As well, lessons learned from Gestalt theories inform the study of human communication with a computer system in key areas and they help to define a number of principles for perception of visual stimuli, including: proximity, similarity, closure, continuity, symmetry; color; attention; memory; and knowledge (Choo, Detlor, & Turnbull, 2000).

Wallace (1993) presents an overview of the cognitive approach to interface design that is perhaps the most theoretical strategy for interface design incorporating the knowledge base of cognitive psychology into a model that strives for optimal design for the learner. Applying psychology addresses the issue of designing interfaces with high usability by focusing on the learner. This “know the learner” approach to design is significant as it is also based on constructivist ideas of how learners process and construct their own knowledge and adopts analysis methods refined in psychological testing. Marchionini (1997) agrees and suggests that for designers to reach the goal of producing interfaces that enrich cognition, they should first understand user interfaces in terms of learner's psychological concerns. Plass (1996) supports both Wallace's and Marchionini's viewpoints.

The concept of *mental models* is also central to the discussion of cognitive psychology and HCI. An understanding of mental models is particularly relevant to the research of this paper as they are integrally related to the study of user success and satisfaction with complex hypertext systems and constructivist learning environments. Mental models are representations of reality that individuals use to understand specific phenomena. Individuals often form schema - internal, mental models - to help provide predictive and explanatory power for understanding interactions with the environment, with others, and with the artifacts of technology (Gentner & Stevens, 1983). Although specific definitions of mental models vary, the basic characteristics include:

- They provide simplified explanations of complex phenomena
- They are incomplete and constantly evolving
- They are often constructions of metaphor, analogy, and similarity
- They typically contain errors and contradictions
- They can be represented by sets of condition and action rules.

Some theorists content that mental models are the basis for all reasoning processes particularly in the detailed analysis of focused knowledge domains such as human-computer interaction (Holland et al., 1986; Johnson-Laird, 1983).

Mental models are specifically used in explaining human interaction with interface design in many HCI theories including key work by Marchionini and

Shneiderman (1988), and Card, Moran, and Newell (1983) and others. For example, the Macintosh operating system was designed according to two fundamental paradigms, both of which assume that users have a working mental model of the system that relates to their understanding of the physical world. The paradigms are based on a form of user action know as *noun-then-verb*. In one paradigm, the user selects an object (the noun) and then chooses the action to be performed on the object (the verb). In the second paradigm, the user drags an object (the noun) onto another object that has an action (the verb) associated with it. For this system to work effectively, the user must have a working mental model of the objects and actions. The design of the *trashcan* icon, for instance, looks like its real-world counterpart supporting the user's mental model and making the interface easier to use (Apple Computer, Inc., 1992).

Jonassen (1999) believes that being able to reliably and validly operationalize users' mental models can help educators to assess advanced knowledge and problem solving skills acquired while interacting with constructivist learning environments. Additionally, he states that understanding effective and ineffective models provides advice for designing scaffolding, modeling, and coaching that should be included in learning environments to support effective mental model development. Examples of constructivist learning environments incorporating the use of mental models in their design include; cognitive flexibility hypertexts, anchored instruction, goal-based scenarios and causally modeled diagnostic cases (Jonassen, 1999; Schank, 1994). Gentner and Stevens (1983) believe that an understanding of the use of analogy and similarity in mental models can lead to substantial improvements in human-computer interaction and in designing better training materials. Also, adult learning preferences and computer self-efficacy beliefs are significant factors influencing the development of individual mental models of educational computer use and I believe that this point is further supported by findings from this study.

Searching and information browsing are overwhelmingly listed as some of the most prevalent uses of the Web by adult learners (see Horton, 2000; King, 1998; Nielsen, 1999; Hackos & Redish, 1998; Wood, 1998) and researchers working in the field of human computer interaction have developed a substantial body of work covering information browsing and visual queries that informs their continued study. Representing information graphically is widely considered a powerful aid to understanding and dissemination and theories on visual queries, browsing and information retrieval have been proposed and tested (Tufte, 1996). The emerging field of information visualization is expanding the boundaries of the ways that computers are used to organize and display complicated scientific and technical data and the technology developed and implemented in these systems is proving to be effective as a teaching and learning aid as well (Card, Mackinlay, & Shneiderman, 1999).

Marchionini (1988, 1997) presents the clearest summary of the issues affecting users seeking information in electronic environments making a particular point of emphasizing the individual differences among users as being of primary importance in studying human computer interaction with his research suggesting that differences in abilities, characteristics, and experiences users bring to their interaction with a computer system are the most significant factors in determining achievement and satisfaction with the use of the system. Based on this assertion, he states that computer systems must have robust interfaces to support the widest variety of users. While he does not specifically mention learning preferences, it is my view that his ideas support the general contentions of this dissertation study.

Navigation is defined as a browsing strategy that includes the ongoing observation of environmental attributes, adjustments to the mental representation based on these observations, and the resulting behavioral actions. Marchionini (1997) lists four primary visual searching operations that are widely recognized and studied:

- structuring objects for examination,
- filtering objects,
- panning to nearby objects,
- and zooming to different levels of detail.

Users typically perform these operations on the Web by manipulating a text and graphical schema that displays objects and suggests relationships and hierarchies of information. Shneiderman (1998) identifies a particular interactive *dynamic query* information seeking methodology that has been widely adapted on the Web. This system uses graphical *sliders* to allow users to dynamically make query changes and receive almost instant feedback from Web-based search systems. Studies of these systems have shown consistently positive results in success and satisfaction rates from both expert and novice users. Shneiderman notes that systems of this type may be best for search features and questions that lend themselves to graphical representation and ordinal criterion (Shneiderman, 1998). This point is particularly relevant to this study as, based on the research results, there is a strong likelihood that learners with preferences for graphical and ordinal elements would have greater achievement and satisfaction with certain search systems.

One of the most pertinent classic theories used in the understanding of human-computer interaction is the GOMS (Goal, Operators, Methods and Selection) model developed by Card, Moran, and Newell (1983). GOMS is a theory of the cognitive skills involved in human-computer tasks and is based on an information processing framework that assumes a number of different stages or types of memory (sensory storage, working memory, long term memory) with separate perceptual, motor, and cognitive processing. All cognitive activities are interpreted in terms of searching a problem space. In the GOMS model, cognitive structure consists of four components:

(1) a set of goals,

(2) a set of operators,

(3) a set of methods for achieving the goals, and

(4) a set of selection rules for choosing among competing methods.

For a particular task, a GOMS structure can be developed and used to predict the time required to complete the task and to identify and predict the effects of errors on task performance. The GOMS model has been applied to a large range of computer tasks and has also been widely adapted over the past few decades as a system design methodology that allows developers to test details of user interface designs (Card, Moran and Newell, 1983).

Marchionini and Shneiderman (1988) have developed a model that represents the *information-seeking framework* and illustrates the determinants of success in interface use and information-seeking in hypertext environments (see Figure 4). Their framework includes the complexity of the task domain, the physical and functional setting, the search system organization and user interface, and the user's mental models and knowledge of each of these elements. The outcome side of the model represents the results of the user's interaction with the artifacts of the constituent elements and the total interaction process. The user's cognitive representation of the situation, comprising the content, structure and relationship of the information related to the human-computer interaction, is essential to the completion of the process and can be vastly influenced by system cues, external stimuli, past experience, and the user's self-knowledge (Marchionini & Shneiderman, 1988). This model can be applied to most HCI situations but seems particularly appropriate for learning applications as the user's (or learner's) interaction and cognitive understanding of the system is central to the process.

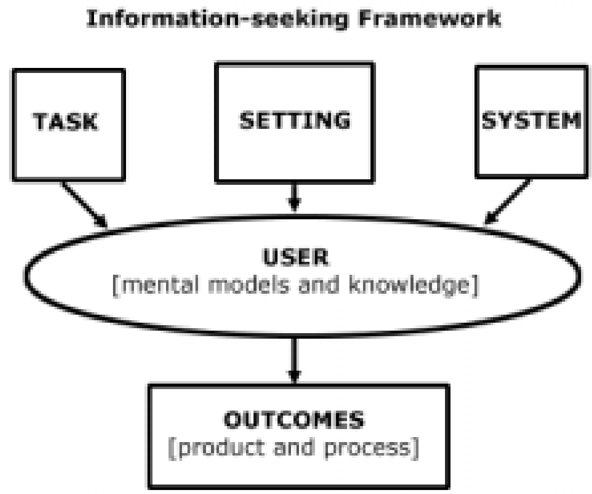

Figure 4 HCI Information-seeking Framework

Perhaps the most inclusive and broad-based methodology of computer system development rooted in HCI research that has emerged in the past decade is Participatory Design (PD). PD is an approach to the assessment, design, and development of technological and organizational systems that requires the active involvement of users in design and decision-making processes (Kyng & Mathiassen, 1997; Greenbaum & Kyng, 1991). PD has relevance to this discussion as it represents a holistic, user-centered approach to human-computer interaction that has considerable potential to improve the usability of Wed-based educational resources. PD practitioners are diverse in their perspectives, backgrounds, and areas of concern; there is no single definition of PD but most practitioners share the following tenets and values:

- Respect the users of technology. View every participant in a PD project as an expert in what they do, as a stakeholder whose voice must be heard.

- Recognize that design ideas arise in collaboration with participants from diverse backgrounds, and that technology is only one option in addressing emergent problems.
- Understand the organization and the relevant work on its own terms, in its own settings by observing and interacting with users in their workplaces (Kyng & Mathiassen, 1997).

Web Interface Design

Given that the visual interface serves as the primary conduit through which a user can interact with and benefit from the computer environment, particularly the graphically intense World Wide Web, the visual design of computer applications is vital to their success as viable learning aids. Computer interfaces are also important translators of internal functionality; they project a necessary, simplified, designed view of the complex information-processing tasks performed by a computer's circuitry (Head, 1999). As Evans and Edwards (1999, page 151) explicitly state, "perhaps the central factor in the usability and effectiveness of learning software applications is the design, organization and implementation of the user interface." Traditionally, the study of graphic design offered little guidance for moving beyond communication to dealing with functionality aspects of interaction so interface design must encompass aesthetic, functional, and performance aspects of the visual organization of an interface. The body of research literature on interface design and human computer interaction for Web-based learning applications, which is vast and seemingly ever-growing, reflects this point and comprises studies of visual design and navigation screen elements and organization and also includes work on theory-informing practice in practical development of Web-based projects.

Although there is virtually infinite variation in artistic design of Web sites, interface screen designs can be deconstructed into groupings of constituent components and controls for purposes of analysis. The following categories of site elements emerge as most often studied and evaluated in the existing literature:

- site content and function design;
- site structure design and organization;
- site navigation control and user interaction elements;
- and site graphic design.

A brief discussion of recommendations and considerations for these key areas synthesized from the plethora of guidelines and handbooks relating to the design and organization of Web interfaces are summarized in the following paragraphs. These suggestions are most often presented in the form of lists of rules and guidelines and are typically phrased as directives to designers. This information is relevant as these practices informed the design of the Web-based educational resources evaluated in this study. As well, these ideas contributed to the suggestions for future improvements to the design of educational Web sites in combination with the results of this study.

In considering Web site content and function, designers should strive to provide content and features that will meet users' needs by making sure that all information presented is important, and that the importance is evident to the user. Site developers should also be sure users can see meaningful information within a few seconds of page download time and the most important content should be in the upper portion of the page as studies have found that users often do not scroll down through pages of text or graphics. Designers should be cognizant of the following when considering Web site structure design and organization: Keep the structure of the site shallow; avoid creating overly deep sites with many levels of pages through which to navigate. Minimize the number of clicks required to access desired information or functionality.

General navigational controls and user input considerations should be designed so that standardization of the navigational elements across the site is the paramount goal. Designers should strive to make the function of all controls obvious and highlight the specialized controls in each section or page. Instructional Web designers should visually indicate which buttons or links are functional and identify the purpose of each buttons or link. For user interaction, visual confirmation should be provided when the user makes a selection. Make data entry as easy as possible through the use of pull-down menus and multiple-choice options and update the screen display with data entered by the user whenever possible.

Research on Gestalt theories suggests that visual design elements and stimuli are significant factors in human's interaction with computer systems (Choo, Detlor & Turnbull, 2000). The influence of established design principles from print and motion media has created some conflicting ideas on recommendations for Web design that is evident in the literature; some authors propose that established principles should be followed and others insist that new and different design criteria should be instituted for the Wed medium (Lynch & Horton, 1999). It is my view that basic aspects of sound graphic design including alignment, balance, contrast, proximity, repetition, and attention to details of type, line, and color should follow best practices established in other mediums.

The following list presents an overview of directives for graphic design considerations for the design and implementation of Web-based educational and instructional material:

- Identity / theme – Adopt a unique site theme that offers a cohesive identity to users. Use the site theme to support the functions and content of the site, while providing visual consistency throughout. Strive to balance a clean and simple interface with visually appealing graphic design.
- Page Layout – Strive for clean, easy-to-view displays that provide needed content without crowding.
- Type – Limit typefaces to a small number of styles. Use italic or bold text conservatively for attention or emphasis. Use variation in font sizes to reflect different functions.
- Color – Select aesthetically pleasing combinations of colors that are appropriate to the site theme. Use foreground and background color

combinations so that text and graphics can be easily viewed on all platforms and browsers. Make sure text and background colors print legibly.

- Media – Use high-quality graphics that support the goals of the site, and integrate them well with the text. Evaluate the importance of numerous and/or large images against their required download time.

While somewhat difficult to quantify, these elements are the most often overlooked features in the implementation of education-related Web sites. This point was confirmed by research data and is discussed further in the Conclusions section of this paper.

The interface element checklist designed for this study identifies the most common screen interface elements in the following categories: browser navigation elements, site navigation elements, screen design elements, screen content elements, and site organization and information structure. This instrument was employed to measure the frequency of use of each screen component during usability test scenarios to quantify the connections between the use of these elements and the test subjects' learning style preference and task performance. The research supporting the connections between use of and success with specific items in each of these categories and preferences of individual users is limited but does support the further investigation of this study (see Felder, 1996; Norman, 1994; Rosenfeld & Morville, 1998; Spool, 1997).

Rosenfeld and Morville (1998) suggest that successful navigation design includes two key elements: a well-designed hierarchical organization scheme and a complimentary navigation system to provide context and to allow for ease of user movement within a Web site. They have found that navigation systems can be designed to support associative learning by featuring navigation elements linked to current screen content. This helps users as they move through a navigation system by enabling them to learn about topics tangentially related to the content for which they were originally searching (Rosenfeld & Morville, 1998).

Fleming (1998) proposes two tiers of navigation questions that should inform the design of interface elements for learning Web sites. The first tier covers general navigation questions and should apply to all designs. The second tier, titled "purpose oriented questions," is specific to navigation design for learning Web sites and includes the following framing questions:

- Where should the learner begin?
- Does the learner need special knowledge or tools?
- How does the learner know what the site says is true?
- How can the learner get information that is right for their needs?

This framework is intended to help designers and supports the idea that learning is cumulative and that meeting these basic design criteria is a solid foundation for all learning-oriented Web sites.

Shneiderman (1998) proposes a set of eight rules specifically for Web interface design aimed at the functionality of the interface: consistency; offer feedback; reduce short term memory load; support a user's internal locus of control; offer error prevention and handling; permit reversal of actions. As well, Horton (2000) makes recommendations for on-line course interface design and organization informed by experience in adult education and training. He suggests five general guiding principles for Web-based course development:

- scaffold content from the known to the unknown;
- keep learning goals at the forefront;
- provide tasks that are purposeful;
- do not let standard Web design principles interfere with learning goals;
- and allow opportunities for students to check their understanding.

Recently many academic and scholarly studies of interface design guidelines have been published giving specific recommendations for page layout and organization of Web interface design. These guidelines address issues of screen elements, theoretical concerns, usability testing, and pedagogical requirements and are relevant to this investigation as the hypotheses state that there is a connection between the use of specific interface elements and learner style preference. Highlights of some of the most relevant studies are included in the following sections.

Borges, Morales and Rodriguez (1998) examined university student use of hypermedia environments on the Web and the university intranet and developed a comprehensive list of design principles. From their study, they concluded that page organization, navigation, and consistency were the key elements in effective Web page design for use by university students. Schank's (1994; 1995; 1998) work also involves adult learners and university students and stresses the value of problem-based learning, learning from experts, and developing skills rather than perfecting routines. His approach to both learning, and training in a corporate setting, involves learning by doing, allowing learners to make mistakes in a safe environment and sharing stories with leading teachers and experts. Schank and Birnbaum (1995) discuss five principles that serve as guidelines for the design of interfaces to educational software stressing that the principles are not isolated and independent from each other. Rather, these principles are intended to form a coherent approach to the problems of interaction and navigation of computer software. It is worth summarizing their justifications here as they present, what many consider, the most sound and well-regarded set of guidelines currently available in the field (Dillon & Gabbard, 1998).

As Schank and Birnbaum detail, the basis for user control of software interface is a practical one. Generally, in order for individuals to operate effectively in carrying out a task, they must understand that task and how it relates to what they are trying to accomplish. When the learner is in control, they have a greater understanding of the actions they can undertake in the system, and hence their use of the system is likely to be more effective. The second principle is essential to implementing the first. Without proper information, users cannot make effective decisions. They argue that computer systems must offer users appropriate choices at appropriate times, and the systems must provide the information necessary to make correct choices. In order to make informed choices, the information a learner needs must be made available to them at the exact point in time when they need to make a specific decision. To be most effective, the system must anticipate the informational needs of the learner. In order for a learner to grasp the relevance of the choices at their disposal, or of the information that they might use in determining which of those choices to make, they must understand how those choices and that information might fit into a given task. This can only happen if the learner and the system both have roughly the same understanding of what that task is. Designers generally want learners to feel good about using the systems they design, and to genuinely want to use it; this is what Schank and Birnbaum call palatability (Schank & Birnbaum, 1995).

Evans and Edwards (1999) research navigational issues for multimedia courseware. Their work, based at Brunel University (UK) involves close observation of student use of proprietary software applications and includes the implementation of design decisions in both multimedia and hypermedia applications. Evans and Edwards' conclusions include concise lists of recommended design and navigation elements as well as an analysis of the problems and benefits associated with the use of educational computer software. These authors also present an effective comparison of common types of digital courseware including computer based training packages and the Web. They focus on navigational elements as the distinguishing factor; where multimedia includes explicit navigational mechanisms and hypermedia relies on implicit linking of related sections of information.

Action Research in others areas of computer software design has also begun to play a limited role in the development of Web-based educational multimedia and hypermedia. Houser and Deloach's (1998) study of student use of recreational computer games has led to new principles they consider to be effective for educational interfaces. They developed seven standards, designed specifically for multimedia educational applications. This connection between multimedia games and educational software has shown to be important among students and is often overlooked by educators but could prove to be an effective model for further cross-disciplinary, research in the field.

Work in the field of Information Design also informs much of the current writing on Web interface design. Information Design involves a multi and inter-disciplinary approach to communication, combining skills from graphic design, technical and non-technical authoring, psychology, communication theory and cultural studies (Tufte, 1983; Horn, 1998). Tufte's (1983; 1996) guidelines, theories, and many examples of effective information displays are helpful for improving complex and simple designs and are critically important for developing effective displays of complex data such as financial data, network status, or performance statistics. They have particular relevance to the Web, where the computer's huge reservoirs of data are fed to the user through the limited space presented on a typical display screen. Human visual bandwidth is capable of handling millions of data points but users typically work with a computer screen that contains fewer than 1,000 characters (Tufte, 1996).

Usability

Computer system usability is seen as an important component of research on human uses of computers and an essential factor in educational models such as minimalism. Although usability has broad influences, it is typically studied as a carefully delimited concept within the fields of HCI and interface design (see Figure 5). Usability is a combination of factors that affect the user's experience with a system and is generally defined by meeting five primary criteria:

- easy to learn
- efficient to use
- easy to remember
- few errors
- and subjectively pleasing.

Usability applies to all aspects of a computer system, or Web site, with which a user interacts. Usability has multiple dimensions and is typically determined through the use of scientific usability evaluation methods (Nielsen, 1994).

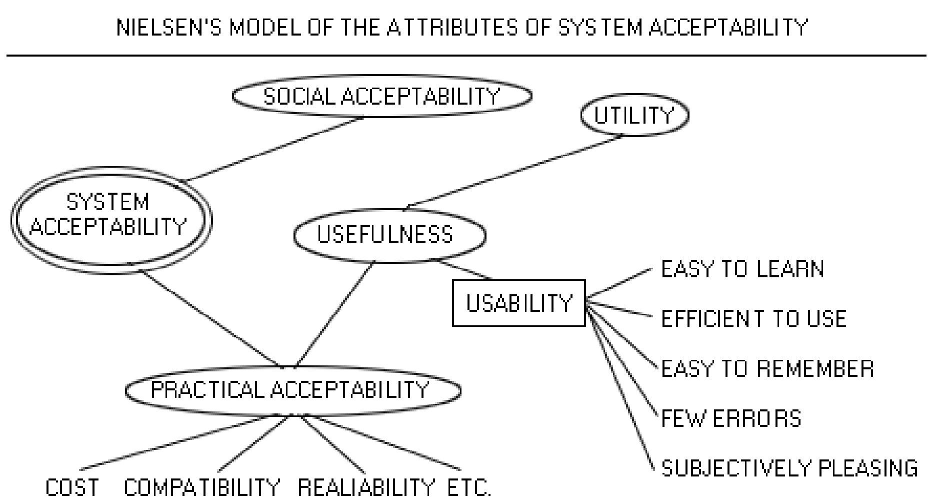

Figure 5 Attributes of System Acceptability

Historically the term *user friendliness* was employed to describe the overall acceptability of a computer system. Recently this term has been replaced by more applicable names, most appropriately *usability*. Within the traditional framework of user friendliness is the idea of system acceptability, a combination of social acceptability and practical acceptability a primary component of this is usefulness (Nielsen, 1994). Usefulness is defined as the issue of whether a system can be used to achieve specific goals and includes *utility* as the idea of whether the functionality of a system does what it is intended to do; and usability the issue of how well the audience can use the functionality of the system. A successful system design in terms of usability depends on solving the dynamic interacting needs of four principal components: user, task, tool, and environment (Shackel, 1984). Systems that are developed using usability design and testing methodologies are often labeled *human-centered* or *user-centered* designs.

Although research is limited on the subject, subjective satisfaction with Web-based educational material may ultimately prove to be the area where there are the strongest connections between student learning style preferences, individual mental models and usability. Nielsen (1994) considers subjective satisfaction to be a particularly important usability attribute for systems used on a discretionary basis as Web sites can be when designed as optional or recommended course resources. Additionally, it is my view that subjective satisfaction is a general idea that is influenced by and influences user’s perceptions of other usability attributes. Visual design, ease and efficiency of use, and errors can all contribute to the subjective satisfaction a user may have toward a particular Web site. This is particularly appropriate to this research study as the combinations of these factors were all considered and evaluated. Supporting this idea, Williams, Paprock, and Covington (1999) report on a study of adult learners using the Attention, Relevance, Confidence, and Satisfaction (ARCS) model that indicates that subjective satisfaction of Web-based distance learning courses can be measured and used to improve future course design.

A large majority of the current writing and practice of user-centered Web design is based on the work of Nielsen (1994, 1995, 1999) and his model of *Usability Engineering* in which he presents a succinct picture of the problems with interface design on the Web and details usability engineering processes and heuristics for evaluation that have become de facto standards. The following ten general rules for interface design and usability are central to this methodology (Nielsen & Mack, 1994):

- Visibility of system status – the system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
- Match between system and real world – the system should speak the user's language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
- User control and freedom – users often choose system functionality by mistake and will need a clearly marked emergency exit to leave the unwanted state without having to go through an extended dialogue.
- Consistency and standards – users should not have to wonder whether different words, situations, or actions mean the same thing.

- Error prevention – even better than a good error message is a careful design which prevents a problem from occurring in the first place.
- Recognition rather than recall – make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
- Flexibility and efficiency of use – allow users to tailor frequent actions.
- Aesthetic and minimalist design – dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
- Help user with errors – error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
- Help and documentation – it is better is to develop a system that can be used without documentation but, if needed, any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Nielsen's usability engineering approach was originally designed for commercial software development but is becoming more prevalent in educational settings as well (Borges, Morales, & Rodriguez, 1998).

In developing the seminal Macintosh graphical user interface, the designers and engineers at Apple Computer codified basic principles for human computer interaction design that help to highlight the value of usability in a successful and influential computer product. The Apple human-computer interface design principles are: metaphors, direct manipulation, see-and-point, consistency, WYSIWYG (What You See Is What You Get), User Control, feedback and dialog, forgiveness, perceived stability, aesthetic integrity, and modelessness (Apple Computer, Inc., 1992). Tognazzini (1992) helped to develop these principles and combines them in practice with a user-focused methodology similar to Nielsen's that he summarizes with three succinct statements:

- effective interfaces are visually apparent and forgiving, instilling in their users a sense of control;
- effective interfaces do not concern the user with the inner workings of the system;
- effective applications and services perform a maximum of work, while requiring a minimum of information from users.

Usability evaluation is principally intended to test the usefulness and utility of a computer system pertaining to the success and reaction of users to the system and usability evaluation methods and practices can have a substantial impact on the effectiveness of a final software product (Nielsen, 1999). Results from Web usability tests are most commonly used to correct errors in a particular Web site design (Nielsen, 1999). In this investigation, the reaction of the user (learner) is more relevant to the research than the usability of the systems itself and these reactions can also be measured with standard usability evaluation methods. Generally, Web site usability is measured relative to users' performance on a given set of representative test tasks. The most basic and essential measures are:

- the time a task requires,
- the error rate, and
- users' subjective satisfaction.

This is an area that is closely examined by both researchers and Web site designers, but often in different ways, resulting in inconsistent outcomes and predicted impacts on learners. Testing undertaken by practicing designers and programmers often focuses on the working functionality of a particular piece of software or Web site, while academic researchers typically concentrate on the generalizable outcomes of usage patterns of particular focus groups. For example, Nielsen's (1994) work for Sun Microsystems involved navigation elements for their intranet system and Schank's (1996) studies of adult learners evaluated general responses to computer based training. Both approaches neglect the testing of Web sites as a unified whole where usability, interface and navigation design, and user understanding and performance are all evaluated as connected elements of a robust picture of system usability and user needs analysis. This investigation took a broader approach that leverages the strengths of multiple evaluation methods.

Historically, recommendations for improved interface design and usability heuristics are made without regard for the nature of content and audience of a Web site. However, a few authors (see Choo, Detlor & Turnbull, 2000; Fleming, 1998; Hackos &

Redish, 1998; Norman, 1994) have begun to make distinctions among the unique needs of particular Web audiences. Hackos and Redish (1998) are the clearest in making a distinction between the usability testing needs of general software designers and instructional designers. In their definition of interface design they list three key criteria, taken from the tradition of rhetoric, stating that interface design should include:

- understanding with who you are communicating (users);
- figuring out how to communicate with them (design);
- and having guidelines for doing so (heuristics).

In their discussion of Instructional System Design (ISD), Hackos and Redish (1998) also note a significant difference between user and task analysis for new software systems and the specific needs of developing training material for existing products. They say that ISD usually begins after a product for which training is needed has been designed meaning that procedures have already been developed and the understanding that instructional designers are seeking is how to get users who do not know the procedures to learn them. They do not specifically link this idea to the design of educational software or Web sites; however, it is relevant to the investigation as it informs a worthwhile usability perspective.

Norman (1999) advances the concept of unique usability needs for educational Web sites as well by emphasizing the need to put the user at the center of design initiatives in technology-based learning. His ideas are applied to Web-based learning where he calls for a new paradigm for effective design for learning. In contrast to traditional courses that Norman labels *teacher-centric* or *content-centric,* his e-learning model is based on understanding how individuals learn. Norman's *learner-centric* approach to on-line learning involves an iterative cycle of design-check-redesign working toward a *pedagogical usability* for e-learning design (Norman, 1999).

Evans and Edwards (1999) build on the established work of Nielsen and Marchionini by focusing on the disorientation problems often encountered by students in multimedia and hypermedia environments. In the development of their 'Virtual Model', they attempt to limit the cognitive overhead on Web navigation by narrowing decision choices into one of three basic models: linear, hierarchical, and network. These models are manifested through three types of navigational tools: sequential, menu, and map. Their research includes tests of the use of these navigational tools by students. They cite work performed by Beasley and Waugh (1995) establishing that using a hierarchical organized map of a hypertext environment aids in navigation for educational applications compared with a non-hierarchical organized map concluding that many disorientation problems encountered by students using multimedia educational software could often be solved with relatively simple navigation and organization schema. Additionally, Rosenfeld and Morville (1998) cover Web site organization schemes in detail focusing on recommended strategies that aid learnability of site navigation.

In another very relevant recent study, Spink (2002), explores a user-centered approach to the evaluation of a Web search engine used by students focusing on the interface design effectiveness, based on the impact of users' interactions on their information problem and information seeking strategies, and usability, including screen layout and system capabilities for users.

Several additional scholars present usability evaluation reasoning and methodologies that are not directly rooted in the work of Nielsen and offer slightly different perspectives. Mullet and Sano's (1995) approach is based on the idea of reduction as a design technique that uses a three-step process:

- determine the essential qualities that should be conveyed in a design,
- critically examine each element in the design and ask why it is needed,
- and try to remove the elements from the design to see if the design collapses either functionally or aesthetically.

Constantine (1994) founds his "Collaborative Usability Inspections for Software" approach on the following six principles: The structure principle directs readers to organize the user interface purposefully, in meaningful and useful ways that put related things together and separate unrelated things based on clear, consistent models that are apparent and recognizable to others. The simplicity principle says make simple, common tasks simple to do, communicate simply in the user's own language and provide good shortcuts that are meaningfully related to longer procedures. The visibility principle directs the interface designer to keep all needed options and material for a given task visible without distracting the user with extraneous or redundant information. Constantine's feedback principle instructs designers to keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions using clear, concise, and unambiguous language familiar to users. The tolerance principle says to be flexible and tolerant, reducing the costs of mistakes and misuse by allowing undoing and redoing while preventing errors wherever possible by tolerating varied inputs and sequences and by interpreting all reasonable actions logically. The author's reuse principle suggests that interface designers reduce the need for users to rethink and remember by reusing internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency.

Redmond-Pyle and Moore (1995) detail their *GUIDE* approach to graphical user interface development. Their system includes seven major elements combined in an iterative approach. Their work also includes examples of successful implementations of the method. Galitz (1997) also adds insight to the issues of testing and usability in developing graphical user interfaces. He includes purposes, strategies and methods for testing as well as, guidelines for specific steps to be used before, during, and after a usability test that incorporates test participants. Mayhew's (1999) usability engineering lifecycle also expands the body of writing on software usability testing with a practical, user-centered orientation. Also researching in the area of Web usability, Fowler (1998) presents an overview of several testing methods organizing them into low impact and high impact categories creating a hierarchy that allows testers to prioritize and measure changes necessary to improve a software product most efficiently. She includes sample testing scorecards and worksheets using Likert-type scales and semantic differentials that support these categories.

Stufflebeam's CIPP usability development model is a process-based model that suggests a contextual approach to usability. CIPP, an acronym for Context, Input, Process, and Product, reflects a user-centered approach to software and Web site development (Stufflebeam & Shinkfield, 1990). Also, Wood's (1998) four-step usability design process integrates user requirements as essential elements in the software design process. Although not specifically focused on Web design, Wood's process is relevant as it follows a multi-step, iterative method that includes key, user-centered elements:

- defining new user tasks,
- defining usability performance objectives,
- designing the system's model for the user,
- and designing detailed screens.

Within each of Wood's tasks are several design-prototype-evaluate iterations that allow for a rich exploration and evaluation of user needs with the goal of ultimately creating more usable software. Wood also presents a clear overview of the use of visual metaphors and their connection to usability that was not well articulated in a large percentage of current research. The use of metaphors is particularly relevant to this study as the World Wide Web is dependant on visual design and often uses graphic metaphors to represent important aspects of learning Web sites (Wood, 1998).

Chapter III: Research Procedures and Methodology

The primary research component of this study employed quantitative and qualitative scientific methods to examine the correlations between adult learners and usability of interface design of Web-based educational material. The study attempts to present a rich, multi-faceted view of the test phenomena and its impact on adult learners by suggesting improvements in approaches to design of Web-based learning resources. In an effort to create the most robust view of the phenomena influencing the success of adult learner's use of Web-based educational applications, many factors related to the test hypotheses were evaluated. Instruments and test procedures were implemented to measure and assess the qualitative aspects of test subject's experience, attitudes towards, and emotional views on using Web-based learning resources and computers. As well, test subject's performance and learning style preferences were quantitatively evaluated and scored.

Research Hypotheses

This investigation is a mixed method study with the primary research viewpoint based on a quantitative, substantive theoretical perspective rooted in three hypotheses:

- Hypothesis 1: There is a strong correlation between observed learning-types and the use of specific navigation elements of Web-based educational resources.

- Hypothesis 2: Screen elements and visual design schemes contribute to the success and subjective satisfaction of adult learners using Web-based educational resources.
- Hypothesis 3: There is a connection between the needs of adult students and Web-based educational material that should be positively improved through the tailoring of the design of visual interfaces of such material.

Research Methodology

The experimental design methodology of this study used a combined, quantitative and qualitative *between methods* study approach of a *dominant-less dominant design*. The study incorporated learning style instruments, satisfaction surveys, interviews, observation, and usability test methods. The research design paradigm assumptions for this study employed a pragmatist approach asserting that there is a false dichotomy between qualitative and quantitative approaches and that researchers should make the most efficient and effective use of both paradigms in understanding phenomena (Creswell, 1994). Justification for combining methods in a single study is established and is highlighted by the following points: triangulation, to seek convergence of results; complimentarity, in that overlapping facets of a phenomenon may emerge; developmental, wherein the first method is used sequentially to help inform the second method; initiation, wherein contradictions and fresh perspectives emerge; and expansion, wherein the mixed methods add scope and breadth to a study (Creswell, 1994).

The questions, assessments, and conclusions of this study thus reflect both the qualitative and quantitative research paradigms. Quantitative data from learning style instruments, usability tests, and satisfaction surveys were combined with qualitative data from interviews and observation to present a balanced view of the test phenomena.

Qualitative and Quantitative Methods

Using qualitative and quantitative research methods, this study assessed the connection between adult student learning style preferences and use, success and satisfaction with Web-based educational resources. Quantitative data from learning style instruments, usability tasks and test scenarios, and satisfaction surveys were combined with qualitative data from interviews and observation in an attempt to present a balanced view of the test phenomena. The primary research viewpoint was from a quantitative, substantive theoretical perspective.

Subjects

The test subjects for this study were 50 adult graduate students enrolled in courses, on a full-time or part-time basis, offered by the School of Education at Drexel University. There were 22 males and 28 female volunteers in the sample with a variety of occupational and educational backgrounds; subjects ranged in age from 25 to 57 years. No additional ethnic or socio-economic demographic information was maintained for the subjects, as these factors were not deemed significant to this study. All subjects had previously used the Web for course-related work in either a traditional, face-to-face classroom setting or in a distance-learning course. All subjects had at least a basic, general comfort level using personal computers and the Web. Subjects were treated according to guidelines published by the Institutional Review Board (IRB) of Drexel University. Volunteers were not paid for their participation in this study. All test results and other measurements were collected for each subject participating in the study. The final results describe group data and were used to make general recommendations and conclusions. The selection of the intact subject population may inhibit the researchers from generalizing the results of the study to a wider population. The implications of the research are intended for designers, educators, administrators, and instructors in hypermedia instructional settings.

Data Collection Procedures

Data collection began after receiving approval from the Dissertation Chair, Committee Members and Drexel University Office of Research. Subjects were coded to maintain confidentially and impartiality. Quantitative assessments were administered first to measure learning style preferences and Web site usability and interface design element preferences. Qualitative measures were gathered through the satisfaction surveys, and subject observation. Conclusions were based on extensive analysis of all data including linear regression analysis using SPSS software. The following instruments and tests were used in this study:

- Kolb Learning Style Inventory Instrument
- Felder / Silverman Inventory of Learning Styles Instrument
- Web Usability Interface Element Checklist
- Usability task test scenarios
- Test subject observation
- Eachus/ Cassidy Computer Self-Efficacy (CSE) Instrument
- Subjective Satisfaction Interview Questionnaire.

Samples of test questionnaires, test Web sites, and surveys are included in this document (see Appendices A-F). The Kolb and Felder / Silverman learning style tests were self administered by each test student. The usability testing, observation and satisfaction surveys were administered by the investigation's primary investigator or by a trained assistant in a Drexel University computer laboratory using both Microsoft Windows-based and Apple Macintosh computer systems with high-speed Internet connections. Administration of the learning style tests required approximately one-half hour and the administration of the usability task test scenarios and satisfaction interviews took approximately three-quarters of an hour per test subject. Data collection was completed over a three-month period from April to June of 2002.

Learning Preference and Computer Self-Efficacy Evaluation

This investigation used two learning style inventory instruments: the Kolb Learning Style Inventory (LSI II-A) and Felder / Silverman Inventory of Learning Styles (ILS). The Kolb Learning Style Inventory (LSI II-A) has been used extensively with adults in university and professional educational settings for nearly 20 years and has been well validated for a study such as this investigation (Knowles, 1990). The Felder / Silverman ILS is still under development and cannot be considered as having been completely validated although a preliminary version of the ILS was tested, the responses were subjected to factor analysis, and some items that were not providing noticeable discrimination were replaced, and the ILS has been used in several studies that closely matched this investigation. Additionally, the Felder / Silverman ILS has a more contemporary orientation to technology-based education and therefore seems particularly appropriate for this study. The results from both learning style instruments were scored according to their instructions and then combined with other test data.

As well, the study employed the Eachus / Cassidy Computer Self-Efficacy (CSE) questionnaire as an additional instrument to aid in quantification of computer experience and attitudes related to Web use. The Computer Self-Efficacy (CSE) questionnaire was self-administered along with the learning style instruments.

Usability Evaluation

The usability methods employed for this investigation used techniques in the three primary areas of usability evaluation: inquiry methods, inspection methods, and testing methods. The following specific methods were used: contextual inquiry, questionnaires, feature inspection, pluralistic walkthroughs, thinking aloud protocol, question-asking protocol, performance measurement as well as qualitative observation of the test subjects by the test administrator. An interface element checklist instrument was employed to measure the frequency of use of each screen element during the usability test scenarios in an attempt to measure the connections between the use of these elements and the test subjects' learning style preference as Hypothesis 1 asserts that there is a direct and measurable connection between these two test factors. Based on my professional experience and research, I have identified the following screen interface elements as the principle elements used in Web site interface design and user navigation: browser buttons, browser address fields, browser menus, drop-down menus, graphics, help/instructions, image maps, indices, in-text hyperlinks, input fields, multimedia, navigation bars, plug-ins, scroll bars, search features, site maps, text.

Usability evaluation is typically designed to test the usefulness and utility of a computer system in terms of success and reaction of users to the system with the goal of improving system elements and functionality that prove to have low usability. In this investigation, the reaction of the user (learner) was more relevant to the research than the usability of the systems itself. These reactions can also be measured with established usability inquiry, inspection, and testing methods (Nielsen, 1994). Particular focus was placed on the usability attribute of subjective satisfaction and heuristics of screen design and navigation elements (Nielsen, 1994). The investigation usability research thus comprised the administration of several tasks to the test population following the general guidelines and heuristics of usability engineering established by Nielsen (1994). The task analysis included evaluation of timed, representative searching, navigation and fact-finding tasks.

Nielsen (1994) presents the following criteria for usability scenarios. A scenario is an encapsulated description of an individual user (learner) using a specific set of computer facilities to achieve a particular outcome under specified circumstances over a certain time interval. Scenarios can be used during user testing if they are developed with enough detail to sufficiently help a user through a specific interaction with the system (Nielsen, 1994). Nielsen (1994) considers the *thinking aloud* technique perhaps the most valid and useful usability testing method. Thinking aloud tests involve having a test subject use the system while continuously thinking out loud and having the test administer listen to their verbalizations. By verbalizing thoughts, researchers are better able to understand how users perceive a system (Nielsen, 1994).

Web-Based Test Resources

Four different Web sites were used in the data collection stage of the study. The sites represented a range of design and navigation organization schemes that were developed by both professional designers and instructors with less visual design training. The sites included: a government-funded, Web-based research database site; a commercially published teacher resource portal; an on-line course site designed using a popular Web design platform; and an on-line course created from scratch by an individual instructor. Test subjects were evaluated interacting with two of the four Web-based resources selected for the study. These Web-based educational resources include representative graphic, interface, navigation, and multimedia elements (browser buttons, browser address fields, browser menus, drop-down menus, graphics, help/instructions, image maps, indices, in-text hyperlinks, input fields, multimedia, navigation bars, plug-ins, scroll bars, search features, site maps, text) to enable a wide variety of test users multiple selection choices in the browsing and searching strategies for testing scenarios. These test sites were selected to represent the type of Web-based resources the test subjects would likely encounter in formal educational situations. The testing scenarios involving these sites were developed to attempt to mimic realistic learning situations. However, subject's experiences with these sites may not reflect the exact interactions they would encounter in more authentic learning circumstances.

Validity of Instruments and Testing Methodology

The validity of the instruments and testing methodology of this study follows accepted standards for educational research as presented by Creswell (1994) and Vockell and Asher (1995). The learning style instruments have been validated to certain degrees of acceptability and the usability testing methods are based on best practices of usability engineering. The satisfaction survey and interview questionnaire were developed based on guidelines from Hackos and Reddish (1999), Lin, Choong, and Salvendy (1997), Nielsen (1994), and Vockell and Asher (1995). The Eachus / Cassidy Computer Self-Efficacy (CSE) questionnaire and scale have been validated in several large-scale, university-based trials.

The Felder / Silverman ILS, usability scenarios, usability verbal protocol exercises, screen interface element checklist, and satisfaction survey were used in a pilot study of adult students at Drexel University during February 2001. Based on the interactions with test subjects and results of this pilot study, the satisfaction survey, usability scenarios, usability verbal protocol exercises and testing methodology were slightly refined. The Kolb Learning Style Inventory and the interview questionnaire were not included in this pilot study as they were not yet available. Refinements to the instruments and testing methodology based on the pilot study include changes to the instructions given to the test subjects, changes in the selection of Web sites to be used in usability testing, modifications to the questions on the satisfaction survey, and items on the screen interface element checklist.

For the pilot study, 25 adult students self-administered the Felder / Silverman Inventory of Learning Styles (ILS) and then completed three, short Web site usability task scenarios attempting to answer simple fact questions from Web sites that were previously demonstrated or referenced in their graduate course on educational multimedia. The test learners were timed and observed during their test scenarios and their use of Web site screen interface elements was recorded on a checklist. The test learners then completed a post-task questionnaire querying their impressions of the test Web sites and their experience and comfort level with the Web. The test administrator then compiled the results. Results from the pilot study, while limited, did suggest additional support for the research hypotheses. The primary purpose of the pilot study was to get a general gauge of the reaction of test subjects to the testing methodology and to refine the test instruments and testing procedures. Both of these goals were accomplished.

<u>Data Analysis Procedures and Timeline</u>

All of the research instruments and other testing procedures were scored according to their instructions or general recommendations accepted as common practice in the field. Test results and observations were collected for each subject participating in the study. The baseline data collected in this study was used to support the research hypotheses and make general recommendations for usability of Web-based educational material for adult students.

The study data collection was completed over two quarter terms at Drexel University. Test data was collected during the Winter and Spring, 2002 terms from 50 volunteer student test subjects and the data analysis and compilation was completed during the Summer, 2002 term.

Chapter IV: Research Results

Overview

The principal, original research component of this dissertation investigation was a mixed method study of adult learners (N = 50) interacting with Web-based educational resources. In order to determine the significance and scope of the connections among the test variables, all of the following were observed: student learning preferences, Web interface design, student self-efficacy, and student satisfaction with their use of the test sites. The study combined both qualitative and quantitative methods and combined the results of the separate instruments and test procedures into a synthesized whole to present a multi-faceted view of the way the above factors affected the test phenomena. The investigation was rooted in three research hypotheses:

- Hypothesis 1: There is a strong correlation between observed learning-types and the use of specific navigation elements of Web-based educational resources.
- Hypothesis 2: Screen elements and visual design schemes contribute to the success and subjective satisfaction of adult learners using Web-based educational resources.
- Hypothesis 3: There is a connection between the needs of adult students and Web-based educational material that should be improved through the tailoring of the design of visual interfaces of such material.

Research data collection was completed in three phases. Each test was administered and scored individually. Fifty adult graduate students (22 males and 28 females ranging in age from 25 to 57 years) volunteered to participate in this study. All subjects were enrolled in courses, on a full-time or part-time basis, offered by the School of Education at Drexel University. All volunteers had previously used the Web for course-related work in either a traditional, face-to-face classroom setting or in a distance-learning course. Initially, subjects completed a set of test instruments including: the Kolb Learning Style Inventory instrument, the Felder / Silverman Inventory of Learning Styles instrument, and the Eachus / Cassidy Computer Self-Efficacy (CSE) instrument. In the second phase, subjects were tested and observed performing two, multi-part, fact-finding, searching and browsing tasks using two of the four test sites. Test subject's performance completing test tasks, the screen interface elements and controls used, and navigation styles were recorded on an Interface Element Checklist. After the completion of the sample tasks, test subjects completed a Subjective Satisfaction Interview Questionnaire. Total testing took approximately 40 to 60 minutes per test subject.

All instruments were scored according to their design. Exploratory data analysis was performed on all data elements to determine where significant relationships occurred and the nature of those associations. The data collected was ordinal and generally exhibited linear relationships where relationships existed, so linear regression was used to analyze the data. Categorical data analysis was also performed where appropriate to look for non-linear patterns, but the improvement in the model fit was minimal. Using SAS statistical software, regression analysis and ANOVA procedures were performed and results were assessed. *Type III estimable functions* were used, as the data sets were unbalanced and several test variables had similar variances; this model was determined to yield the most accurate results. The 'Type III (Marginal) model' computations automatically correct for as many other factors in the model as possible and provide estimates that are not dependant on the frequency of observations in any group (see Cody & Smith, 1991; Milliken & Johnson, 1992). Also, it was concluded that the 95% confidence interval ($\mu = 0.05$) would be used to validate the credibility of the results. For each test, probability values were evaluated to establish whether the independent variable had a predictable impact on the dependent variable (resulting in a linear relationship) against the null hypothesis that they did not. For each comparison of variables, positive linear relationships were deemed to be supported if $p < 0.05$; in these cases, the null hypothesis was rejected and the alternate hypothesis accepted. As appropriate to the testing scenarios, assumptions inherent in the statistical models were followed; certain tests looked for linear relationships while others did not assume linearity in variable comparisons (Cody & Smith, 1991).

Overall, investigation findings identified causal relationships among the test phenomena and supported the assertions of the research hypotheses, although not all of these correlations were significantly upheld. Qualitative measures showed that test subjects with different learning style preferences had unique predilections for individual interface elements and navigation designs but they all perceived Web sites with clearly organized navigation menus, effective search features, and lists of content choices to be the most attractive (subjectively satisfying), easy to use, and effective in facilitating learning. The most significant quantitative connections proved to be between learners with strong preferences for either end of the Visual-Verbal dimension of The Felder /

Silverman Inventory of Learning Styles (ILS) and correspondingly higher use of either graphic (for visual learners) or text (for verbal learners) interface elements. As well, positive scores and positively phrased comments on a Subjective Satisfaction Interview Questionnaire validated Hypothesis 2 with the idea that screen elements and visual design schemes contribute to the success and subjective satisfaction of adult learners. Also, the connection between higher scores on the Eachus / Cassidy Computer Self-Efficacy (CSE) questionnaire and general satisfaction with the test Web sites was supported.

Perhaps the most challenging aspect of both analyzing the data and drawing conclusions from the findings, was synthesizing the results from multiple instruments and providing specific recommendations for the visual design of Web-based educational resources. Several multi-dimensional patterns were identified in the data and are explained in the following sections. Cross-instrument patterns are curious and noticeable in the data; however, they generally were not upheld by statistical analysis nor did they support coherent outcomes. By amalgamating all of the research and data elements and distilling this information into a concise list, design recommendations for Web-based educational resources were developed; the final list is presented in the Conclusions section of this paper.

The following sections present a summary of research data and commentary organized by test instrument and procedure. To fully understand the connections among the data points, this information must be viewed in the context of their interactions and significance to the research hypotheses. Samples of the test instruments and complete research data tables are listed in Appendices A-J.

<u>Kolb Learning Style Inventory</u>

The Kolb Learning Style Inventory instrument (LSI 2) is designed to assess student's general learning style preferences and tendencies; it includes 18 questions in two sections (see Appendix A). All test subjects completed all questions on this instrument. As previously described (see Chapter III, Learning Preferences), Kolb's model includes a four step learning process: Watching [reflection], Thinking [assessment], Feeling [emotion], Doing [exertion], and a description of the four learning styles used within the process: Reflectors, Theorists, Pragmatists, and Activists. The Kolb results generally did not show a statistically significant support of the hypotheses. However, when combined with the qualitative data, there were noteworthy patterns of behavior revealed through the use of the Kolb instrument.

Table 2 Kolb Learning Style Scores

Kolb Type:	Kolb Description:	Kolb Type /All Test Subjects:	Percent of All Test Subjects:
Type 1	Watcher / Reflectors (concrete, reflective)	5/50	10%
Type 2	Thinker / Theorists (abstract, reflective)	9/50	18%
Type 3	Feeler / Pragmatists (abstract, active)	15/50	30%
Type 4	Doer / Activists (concrete, active)	21/50	42%

Table 2 presents a breakdown of the Kolb data by type and percentage of test subjects. Test subjects categorized as Type 2, 3 and 4 used more icons, text and total actions, than did Type 1 learners, when performing the test tasks; this is consistent with the general descriptions of these types according to Kolb. Type 2 learners typically respond to information presented in an organized, logical fashion and benefit if they have time for reflection. Type 3 learners often respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. Type 4 learners typically learn successfully when applying course material in new situations to solve real problems.

Analysis of the Kolb data shows that results were not statistically significant. The test goal was to determine if there was a relationship between the Kolb learning style instrument scores and subject interaction with interface elements. To do this the following comparisons were analyzed: Kolb v. Proportion of Graphic Actions and Kolb v. Total Actions. Table 3 summarizes the results; for complete results, see Appendix J.

Table 3 Kolb Data Analysis Summary

Proportion of Graphic Actions					
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Proportion of graphic actions	1	0.01643752	0.01643752	0.02	0.9002
Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	
Intercept	3.002961663	0.62790517	4.78	<. 0001	
Proportion of graphic actions	0.162206668	1.28691191	0.13	0.9002	
Total Actions					
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Total Actions	1	1.57919726	1.57919726	1.58	0.2154
Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	
Intercept	3.868446491	0.64382971	6.01	<. 0001	
Total Actions	-0.019202301	0.01529645	-1.26	0.2154	

The Kolb data from this study follows the patterns predicted by previous studies using this instrument (see Knowles, 1990). Although not validated, general patterns were identified that could be seen to maintain both Hypothesis 1 and Hypothesis 2 by supporting the idea that a wide range of learner types are better served by Web designs employing a variety of screen interface elements and navigation designs (see Appendix I). The Kolb results did not support other significant patterns related to the test hypotheses. Also, this data served to stratify the test subject's learning preferences along different dimensions than the Felder / Silverman results.

Felder / Silverman Index of Learning Styles

The Felder / Silverman instrument includes 44 questions and scores subjects along 4 parallel axes ranging (in odd numbers) from 1 in the center of each axis to 11 at either end (see figure 6). The Felder / Silverman learning dimensions are: Sensing - Intuitive, Visual - Verbal, Active - Reflective, and Sequential – Global. Learner's responses are plotted along each axis and then classified according to their preferences. Per the instrument instructions, subjects were grouped into three broad categories (strong [9-11], mild [5-7], or balanced [1-3] preference) for each dimension. However, for the purposes of statistical analysis, the Felder scales were amended into an ordered numerical range from -2.5 to 2.5 so that ordinal, rather than categorical, models could be run on the data.

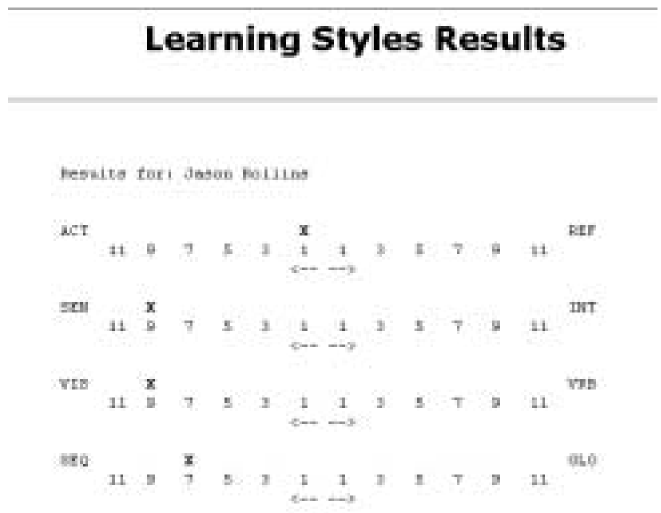

Figure 6 Sample Felder / Silverman Results

All subjects completed all questions on this instrument. The clearest quantitative connections among test data elements proved to be between learners with strong preferences for either end of the Visual-Verbal dimension. Students who scored highly (a score of 9-11 is considered a very strong preference for a dimension of the ILS scale) on one dimension of the Felder / Silverman Inventory of Learning Styles showed unique preferences for the use of specific screen elements. Of the 26 students who scored a 9 or higher on either end of this dimension, all but one subject (96%) displayed a similarly strong reliance on corresponding screen elements in the test searching and browsing tasks. Subjects with high scores on the ‘Visual’ end of the dimension displayed a notable preference for graphic and multi-media elements in both their task performance and subjective comments; conversely, those subjects with a high score on the Verbal end of this dimension had a marked preference for text and text scanning. This was significantly supported by statistical analysis ($p < .0001$). The test goal was to determine if there is a relationship between the Felder / Silverman learning style instrument scores and subject interaction with interface elements. To do this the following comparisons were analyzed: Felder / Silverman (all dimensions combined and separately) v. Proportion of Graphic Actions and Felder / Silverman (all dimensions combined and separately) v. Total Actions. Table 4 summarizes the results; for complete results, see Appendix J.

Table 4 Felder / Silverman ANOVA Summary

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	0.28560	0.28560	40.42	<. 0001
Error	48	0.33914	0.00707		
Corrected Total	49	0.62474			
Root MSE	**R-Square**	**Dependent Mean**	**Adj R-Sq**	**Coeff Var**	
0.08406	0.4571	0.47494	0.4458	17.69828	
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	1	0.47416	0.01189	39.89	<. 0001
Visual/Verbal Score	1	-0.03893	0.00612	-6.36	<. 0001

Other patterns also emerged from scores on additional dimensions, however these were not validated. For example, several students who scored 11 on the *Active* end of the *Active- Reflective* dimension of the ILS used a wide variety of screen elements many times in their test task scenarios and completed the tasks in a faster than average time. These results generally uphold Felder's idea that *Active* learners learn best by trying things out. Test subjects who scored highly on other learning dimensions also can be seen to support Felder's learning style profiles and all three hypotheses. As per Felder's description, test subjects with a preference for the *Reflective* end of the *Active-Reflective* dimension used many more actions then those with a more balanced score, which also supports the hypotheses. As predicted, students who scored as “fairly well balanced” on a learning axis (a score of 1-3 on any dimension of the ILS) did not display strong patterns in their usage of screen interface elements.

Several test subjects scored in the range of “very strong preference” (9-11) for more than one dimension of the ILS so multi-dimensional patterns were also noticeable from the test results but these patterns did not reveal significant or conclusive relationships. The Felder / Silverman results also served to stratify the test subject’s learning preferences along different dimensions than the Kolb instrument. Also, I intended the use of these two dissimilar learning style classification schemas to enhance the validity of the data. A certain amount of redundancy was intended to minimize the possibility of skewing the research results by reducing the reliance on a single model. A comparison of the results of each Felder / Silverman dimension and the Kolb scores was statistically analyzed but no significant relationships were determined (see Appendix J); however, it is important to note that these instruments were not specifically designed to be compared or contrasted but in this case the use of two different instruments did add a multi-dimensional view to the analysis of the test subject’s learning preferences.

Eachus / Cassidy Computer Self-Efficacy (CSE) Instrument

The Eachus / Cassidy Computer Self-Efficacy instrument Includes 40 questions relating to subject’s experience with and views on computer use (see Appendix B). All subjects completed all questions on this instrument and scores ranged from 119 to 188 out of a total of 196. Higher scores on this instrument indicate a stronger confidence in one's experience with computers as well as a higher likelihood to succeed with computers.

The Eachus / Cassidy data helps to support Hypothesis 2. Generally, the data can be seen to show that the higher the self-efficacy belief, the higher the satisfaction rating but this contention was not consistently validated. The connection between higher self-efficacy and the 'easy' component of subjective satisfaction was upheld (p = 0.0360); however, the support for this connection is marginally significant and further testing would be needed to provide more conclusive evidence. Connections between self-efficacy and the 'satisfied' component of subjective satisfaction were not supported (p = 0.3701). Table 5 shows a summary of this data; see Appendix J for complete results.

Table 5 Eachus / Cassidy Data Analysis Summary

Eachus / Cassidy Subjective-Easy:					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	1482.62200	1482.62200	4.66	0.0360
Error	48	15287.45800	318.48871		
R-Square	**Coeff Var**	**Root MSE**	**Eachus / Cassidy Mean**		
0.088409	11.46048	17.84625	155.7200		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Easy	1	1482.622001	1482.622001	4.66	0.0360
Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	
Intercept	127.6099343	13.27068178	9.62	<.0001	
Easy	7.3586560	3.41059615	2.16	0.0360	
Eachus / Cassidy Subjective-Satisfied:					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	281.24494	281.24494	0.82	0.3701
Error	48	16488.83506	343.51740		
R-Square	**Coeff Var**	**Root MSE**	**Eachus / Cassidy Mean**		
0.016771	11.90227	18.53422	155.7200		
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Satisfied	1	281.2449413	281.2449413	0.82	0.3701
Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	
Intercept	143.1966874	14.08649367	10.17	<.0001	
Satisfied	3.1152519	3.44290610	0.90	0.3701	

Patterns of behavior that suggest a link between self-efficacy and subjective satisfaction emerged, as illustrated in the “Eachus vs. Ease”, “Eachus vs. Satisfaction”, and “Eachus vs. Subjective Total” data charts (see Appendix I), particularly in combination with observation of test subject’s performance and their subjective comments. This could be seen to support the assertion that higher self-efficacy beliefs result in greater satisfaction using computers. Also, this data could be viewed as supporting Hypothesis 3 in that it is important for adult students to have a solid understanding and comfort level with computers for learners to be successful using them in educational situations; however, further testing is needed to provide more conclusive evidence supporting these contentions.

The direct connections between interface navigation design and self-efficacy is less obvious but is also suggested by the data. The “Eachus vs. Action” table shows a fairly even distribution for all but the highest scores. I believe this could be explained by the idea that those subjects with lower self-efficacy use many actions because they are less confident in their choices and need to try more options to find answers and complete tasks. Also, 11 of the 12 highest scores (meaning most confident in their computer use) showed very low numbers of actions possibly indicating that these users were self-assured in their choices and had to click and search less often to find the answers to complete the test tasks. This second point is consistent with the assertions of Hypothesis 2 and 3 especially when combined with the subjective comments of these subjects who generally rated the interface design of the sites very highly regardless of their self-efficacy score or their general performance on the test tasks.

Subjective Satisfaction Interview Questionnaire

The Subjective Satisfaction instrument designed for this study includes 11 questions (see Appendix E). Subjects were permitted to answer only those questions on which they were interested in commenting, although most subjects (48/50 [96%]) answered all questions. The instrument includes five questions that were compiled and analyzed along with quantitative data from the other instruments. This is listed as *Subjective Total* on the data tables (see Appendix I). These five questions had Likert-type scales ranging from 1(Difficult/Poor) – 5(Easy/Excellent). Four of the remaining questions specifically addressed design and navigation aspects of the test sites while the two other questions were worded to allow for open-ended answers on satisfaction or personal experience with computers. The answers to these questions along with any subjective comments recorded on the Interface Element Checklist comprise the subjective test data.

This test comprised asking subjects whether the design of the sites impacted their success and satisfaction with the use of the sites. The visual design was assessed by allowing subjects to state what the most “aesthetically pleasing” aspect of the sites was and what was “the most helpful or useful” element of the sites. The test was designed in this way because reaction to the design is a highly subjective area that is very personal to the individual user. The data from this test suggests that the visual design of the sample sites was significant to test subjects.

Table 6 presents a summary of the most prevalent subjective answers to the qualitative questions. I organized the disparate wording of these answers into common clusters based on similar word choices and themes and then listed the five most popular grouped responses. For some questions, all subjects combined gave fewer than five different answers; in these cases, all answers are listed in the summary table. Table 6 represents a large majority of all responses, as the answers were generally homogeneous; there were not more than eight different replies to any one question.

Table 6 Qualitative Survey Response Summaries

Survey Question:	Most Popular Answers:
"What was the **most helpful or useful** element of the design of the Web site(s)?"	• Site organization • Interface / navigation controls • Color • Search • Instructions / help
"What was the most **aesthetically pleasing** element of the design of the Web site(s)?"	• Color • Graphics / pictures • Animation / multimedia • Text / layout • Navigation
"Did you prefer to navigate through the site(s) mainly using **text links**, or **graphic icons**?"	• Graphic icons • Text links
"What **experience** do you have using the Web in courses you have taken?"	• Used Web for research for face-to-face class • Used Web for in-class activity • Used Web for email • Took Web-based class
"Please give any comments you have about your opinion of the Web sites used in the experiment. You may mention color, organization, design, language, or anything else that influenced your experience with these sites."	• Easy to use • Looks / seems professional • Able to find info / navigate at own pace • Attractive colors / graphics • Hard to find information
"Is there anything else that you feel influenced (positively or negatively) your opinion, success or satisfaction with these Web sites – such as your ability using computers, your educational or professional experience or any other personal factors?"	• Sites well designed / organized • Part of experiment / learning styles • Not enough time to find answers • Not experienced using Web • Would be easier if I was familiar with site(s)

The responses on this questionnaire suggest the importance of subjective satisfaction in the test subject’s view of the test sites. Most test subjects rated the design of the test Web sites highly regardless of their preferred learning style. This positive reaction was also not discriminated by other test factors, such as whether subjects completed the test scenario tasks in a faster than average timeframe, or if they asked for help from the test administrator. Comments stating that site organization, interface and navigation controls, color, graphics and text layout were important to the adult students predominated and far outnumbered any mention of page-loading speed, reliability of site content, security, or other pedagogical, technical or administrative issues. These results support an underlying assertion of this research study as expressed in Hypotheses 1 and 2; the visual design and usability of an educational Web site has a direct influence on student’s perceived value of the technology.

Students who had more general experience using the Web indicated that they felt more confident with the test scenarios than those students with less Web experience. As well, allowing the subjects to consider their learning style preferences simply by telling them that was the issue being tested showed to be important to many of them. This was reflected in their comments and is consistent with the success that both Kolb (1984) and Felder (1996) have had in introducing learning style information to adult students. Many subjects (of all learning preference types and with varying degrees of computer self-efficacy) noted that having control over the pace at which they explored the sites and the options to find information in different ways were important to their satisfaction with the use of the sites; these comments also supported the ideas that navigation and computer experience are factors in student success using the Web.

Interface Element Checklist and Usability Task Scenarios

The Interface Element Checklist created for this research includes a grid of 20 commonly used screen design elements (see Appendix D). The instrument includes items like Web browser elements (browser address fields, and browser buttons/icons) and Web page elements (drop-down menus, graphics, help/instructions, and icons). This list was compiled by evaluating the constituent visual elements of dozens of existing educational Web resources and refined after the pilot test. This instrument was employed to record the type and frequency of each interaction (use of a screen element) a subject had while attempting to complete the test tasks. On this instrument, the administrators also recorded subjective comments relating to navigation style and performance completing the tasks. The totals for graphic elements, textual elements, and all elements used were recorded and compiled.

It was suspected, and later confirmed by results, that frequency of use as well as the type of interface elements used would support the contentions of the research hypotheses. The totals ranged from 21 to 60 actions carried out by an individual subject to complete their test tasks. These numbers are not necessarily so straightforward as they can be viewed in several ways. As mentioned in the discussion of the Eachus / Cassidy data, one interpretation of these results is that more confident learners use fewer actions as they are more sure of their choices when navigating. Another interpretation of this data could be that certain learner types, regardless of their self-efficacy beliefs, use more actions when navigating the Web, as exploration and trial-and-error are typical learning methods used by these learner types. The high number of total tasks that both Kolb 'Type 3 learners' and Felder 'reflective learners' used could support this view. I believe that these are both valid and plausible interpretations but that more investigation into these viewpoints is necessary to make more confident judgments. More study into this specific question may reveal further significant connections between learning styles and navigation styles. This is suggested in the Recommendations for Further Research section of this paper.

The test scenarios were fact-finding and searching tasks that are representative of tasks typically performed by adult students in Web-based learning situations (see Appendix F). The testing scenarios involving these sites were developed to attempt to mimic realistic learning situations. However, subject's experiences with these sites may not reflect the exact interactions they would encounter in more authentic learning circumstances. Each subject completed two tasks one on each of two different Web sites. The test administrators recorded performance time and success in the Notes section of the Interface Element Checklist. All subjects completed all tasks successfully although in many cases the test administrator gave some minor assistance. This point should not be viewed as significant to these results as the perception of success, and the overall Web experience were the more important test factors than the actual speed or accuracy of the completion of the test tasks. Based on this perspective and the difficulty of accurately measuring test performance and speed these usability-related test data were not used in the final data analysis. Student learning and success was gauged by a combination of the test subject's ability to complete the test tasks, their comments on the satisfaction survey, and the observation of the test administrator. Subjects were asked follow-up questions to the test tasks and then were permitted to comment on these questions on the satisfaction survey.

Corollary Results

Another pattern emerged from the data that is not completely consistent with the primary goals of the research but I view as a curious and noteworthy corollary. The pattern of connection between self-efficacy, success, and overall satisfaction of subjects with their test experience and the test Web sites is incongruous with most of the other results but may suggest another significant dimension to the perception adult students have of themselves interacting with computers, or possibly, in formal educational situations in general.

In many cases, subjects rated their experience very highly regardless of their self-efficacy score, actual performance in test scenarios or their individual comments on the subjective surveys. Although, for subjects with strong self-efficacy scores and robust performance this makes sense, for others it does not. These data elements were often contradictory for individual subjects but created an overall pattern of high scores on the subjective satisfaction questions and low performance and negative subjective comments.

For example, I observed several subjects who seemed lost in their attempts to complete the test tasks and relied on test administrator assistance to navigate the sites but listed high satisfaction with their experiences and high computer self-efficacy. Also, several other students wrote that they were not comfortable being watched while using the computer for the test scenarios but they still rated their overall satisfaction very positively. Many of these same students clearly did not read or completely follow the instructions for the test scenarios but still said they were confident and happy with the experience.

Although additional data would be needed to do a more conclusive analysis of this trend, I suspect that this may be explained in part by the idea that many students were concerned both about the test administrator's perception of their abilities and their own performance on the tasks. As a result, many students ignored their true experience and beliefs and recorded false positive marks on the test instruments.

Limitations and Improvements to Test Procedures

Several limitations were recognized in the test measures and instruments that did not appear in the pilot study and that might be improved in a future implementation of a similar test.

The most notable specific issue identified in the testing procedures and results was incongruence between the performance of many subjects and their own assessment of success and satisfaction with the test tasks. As mentioned in the Corollary Results section above, this may be explained by inherent biases in the perceptions of the participants but may also be attributed to a flaw in the design of the test. I suspect that a test environment that physically isolates the subject from the administrator could be a possible remedy to minimize the issue of participant’s concerns about administrator’s perceptions of their abilities. A test setting of this type would be consistent with the arrangement typically used in commercial usability labs; however, this type of facility was not available for the dissertation research. Further testing with refined instruments and procedures may reveal a more conclusive answer to this uncertainty. This is suggested in the Recommendations for Further Research section of this paper. Also, the difficulty of accurately measuring test performance and speed of test task may also have been more easily managed had the test environment been more controlled; as to some extent, environmental factors seemed to influence these aspects of the testing.

Another limitation of the study may be revealed through the connections between the use of screen elements and the various learner types and self-efficacy. As discussed in the Interface Element Checklist and Usability Task Scenarios section above, analyzing data considering all of these factors allows for several plausible interpretations. The uncertainty of these readings of the results could be explained by a lack of consistency in the instrumentation and the organization of the test results. This is also mentioned in the Recommendations for Further Research section of this paper.

The use of a more robust learning style instrument could also possibly improve the general validity and richness of the learning style-related results. Ultimately, I was not entirely satisfied with the classifications of the learning style instruments employed for this experiment. Unfortunately, I could not find any single instrument or combination of existing tools that seemed to provide a truly full, multi-dimensional picture of individual learning preferences. Although some of the conclusions based on test results were strongly supported, I thought a tool (or set of instruments used together) that provided a more robust definition and classification scheme would have been more helpful in describing and classifying learner preferences. Perhaps developing a tool of this type and then refining it in a test situation similar to the one used in this study would also be worthwhile.

Chapter V: Summary, Conclusions, and Recommendations

Summary

Whether used as a tool to enhance a traditional classroom, or as the delivery channel for distance learning, the recent impact of the Internet on adult education has been substantial. A significant challenge to educators growing from the emergence of this medium is the ability to harness and adapt the power of these technologies to suit a broad range of adult learners. This question has not been thoroughly explored in existing scholarly work and additional research was necessary to identify the issues affecting these interactions. Addressing this challenge, this study investigated the connections among adult student learning preferences, student success and subjective satisfaction with the use of Web-based educational resources, and the visual design of these resources. The overall goal was to identify the important factors within these connections.

Research results supported the assertions of the hypotheses stating there is a significant connection between learners with strong learning style preferences and success with particular interface design elements and navigation structures of educational Web sites. Furthermore, the research findings suggested that the subjective opinions and accumulated personal life experience of adult students contribute significantly to their satisfaction with Web-based educational resources along with the perceived effectiveness of these resources for learning.

The work of scholars in several academic disciplines was particularly relevant to this study and served to frame the research questions. Authors writing on adult learning, learning preferences, Web-based learning, Web interface design and human-computer interaction, and Web Usability formed the foundation for understanding the breadth and magnitude of the research results.

The pre-existing research supporting the connections between Web interface elements and preferences of individual users was limited, but did support the further investigation of this study (see Felder, 1996; Rosenfeld & Morville, 1998; Spool, 1997). Additionally, the use of learning style instruments has shown valid evidence of the impact of learning styles on Web-based course material (see Felder, 1996). Usability testing of Web-based material is also an emerging area that informed the methodology of this study; leading usability theories (see Nielsen, 1994; Hackos & Redish, 1998; Norman, 1994) incorporate learnability as an essential element laying additional foundational support for this investigation's research findings by closely relating usability and learning.

Generally, scholars have recognized that all learners have some strengths, preferences, and weaknesses in modes of understanding educational material (see Knowles, 1990; Kolb, 1984; Pask, 1976; Robotham, 1999). Learning styles have been used to develop instructional strategies and materials that are effective for a given individual and learning task, however, research has not identified conclusive relationships between these factors. Recent studies (see Clark & Lyons, 1999; Curry, et. al., 1999; Cushing, 1998; Digilio, 1998; Lucas, 1999; Martinez, 1999; McLoughlin, 1999) have shown strong evidence to support the matching of instructional material with existing student learning strengths, but discussion continues over the exact implementation of these ideas.

Within the educational research community there is a long-standing debate over the value and understanding of learning style classifications and theory. This study is written with an appreciation of the contentious nature of this topic and has adopted the *learning centered approach* to learning preference research, a perspective that focuses on learners' active response to the learning task and the learning milieu. This approach to learning style theories and instruments has been successful in three broad areas: creating awareness among educators that learners have differences; instigating learners to explore their preferences; and as a catalyst for discussions about best learning and teaching strategies and practices in various mediums and environments (Knowles, 1990). The results of this investigation help to both broaden and focus these successes: broaden by providing supporting evidence for the successful connections between learning styles and educational technology, and focus by making recommendations for approaches to exploiting the connections between adult student learning strengths and Web site design strategies.

Adult student satisfaction using Web-based educational material proved to be an area where significant connections between student learning style preferences and usability arose. This was important to the study as the pre-existing research suggested that student learning style preferences, adult's attitudes toward formal educational situations, and adult student performance using technology could contribute to an individual's subjective perception of the value of an educational Web site. The findings of this investigation help to further validate and assess this contention.

During the research of this paper, several notable anomalies in the existing literature were identified and clarifications were added to further define both this study and the growing body of knowledge in the field. Most notable is the lack of a widely accepted, succinct, and clear working definition of an *adult learner*. Some authors relied on a rather strict, chronological definition (typically age 25); many others did not specifically define adult learners but instead they proceeded directly into a listing of their academic and educational needs. In both cases, I felt this was inadequate to properly frame this study. Based on my research, I asserted that an adult learner should be defined as *an individual who is a student* and who also meets one or more of the following criteria:

- defines oneself professionally as primarily something other than a student;
- has taken on mature responsibilities at an age when typically one would be principally focused on schooling;
- is of a non-traditional age for a college or university student.

Although this definition synthesizes some of the ideas of Knowles (1990) and Brookfield (1986), it should be largely viewed as an original contribution of this research study.

Another weakness in much of the extant scholarly and professional writing is the focus on the differences between the relative success or failure rate of the use of the Web in either face-to-face environments or in distance learning situations compared to traditional educational practices. I did not find these viewpoints to be particularly worthwhile or relevant as effective design, organization, and implementation of Web-based educational material has shown to work well in many different applications across various environments (see Felder, 1996; Clark and Lyons, 1999; Horton, 1999; Squires, 1999). This investigation attempted to support this assertion and to make general recommendations for Web designs that can be applied to Web-based instructional projects in a variety of settings.

Qualitative and quantitative data was combined to develop a multi-faceted view of the research questions. Two areas emerged from the quantitative data as particularly significant. The evaluation of the Web site test tasks results with some of the learning style and self-efficacy instrument scores clearly indicated support for the research hypotheses. Also, the qualitative responses on the satisfaction survey strongly denoted the importance of subjective satisfaction to the test questions. Regardless of learning preference types or level of computer self-efficacy, most subjects felt that site design, organization, interface controls, color, graphics and text layout were significant to their success and satisfaction in using the Web for learning. Equally important was having control over the pace at which they explored the sites and the options to find information in different ways. This is consistent with the published profiles of adult learners and proved to be important to most test subjects; together these data points validated the three research hypotheses.

Conclusions

The use of Web-based educational resources in higher education has had a substantial impact on adult students. The success of how this technology is adapted to the needs of these learners will be determined by efforts to create tools that cultivate positive and effective learning experiences and build on students' capacities to integrate knowledge and construct their own understanding. Research findings suggest that student learning style preferences, adult learning attitudes toward formal pedagogical situations, and student performance using technology all contribute to an individual's perception of the value of an educational Web site. Generally, the data indicated that the personal, subjective, preferences of individual learners most strongly influenced their success and satisfaction with the test sites. There were many commonalities among preferences for interface design elements from all learner types as well there were noticeable patterns for several unique learning styles. The site designs that supported the broadest range of learner types and navigation and searching strategies were most widely perceived as being effective and aesthetically pleasing. Web site graphic design, often referred to as site *look and feel*, includes the attributes of visual metaphors, site theme, page organization, text layout, color, graphics and media; these visual elements proved to be significant to most users. In answering survey questions on visual design, a majority of comments from subjects noted that page layout, organization, and color choices proved to be the most "helpful" or "aesthetically and subjectively pleasing" elements of the test Web sites more so than site content or even the success of the subject interacting with the site. These results strongly support the underlying assertion of this research study, that the visual design and usability of an educational Web site has a direct and substantial influence on students' perceived value of the technology.

Building on this, I have synthesized current published writing, test data and statistical analysis, observation of subjects interacting with the test Web sites, comments from test subjects on preferred design and navigation elements and strategies, along with my own personal experience and intuition to develop the following 10 general design recommendations. These are proposed to be employed to develop Web-based learning resources that are more usable and more effectively meet the learning needs of a broad range of adult learner types:

1. Present site content in various organization schemas and through multiple media.
2. Design the site/application to support self-paced exploration.
3. Use balance, alignment, and other proven aesthetic principles in designing page layout, organization, graphics, and color.
4. Include succinct, short, clear instructions within the navigation design as well as in any supplemental printed material.
5. Include well-organized navigation menus, effective search features, and lists of content choices.
6. Include a wide variety of screen controls and navigation clues that support a broad range of learner types.
7. Make it easy for the user to retrace their steps or actions through the site.
8. Design the site so that it can be used flexibly, in linear and non-linear fashions.
9. Integrate the site organization into the display of navigation controls but do not allow site structure to dictate visual design.

10. Test site designs with real learners and refine designs based on feedback from test subjects.

These recommendations are intended to be general guidelines that should be tailored to the specific context and needs of individual Web-based learning projects. This list should be a useful guide for designers, educators, administrators, and instructors and could serve as the foundation for future research and practice on improving Web-based learning for adult students.

There remain significant questions to be answered about the connections emerging at the crossroads of the dynamic fields that inform the use of the Web to facilitate adult learning. The results and recommendations of this study provide further insight into the developing domain of adult, Web-based learning and the significance of learning style preferences, student satisfaction, and usability of interface design on this field. It is intended that this work may serve a productive and informative role in future implementations of Web-based educational resources that are more effective in supporting a wide range of adult learners and in facilitating growth and learning, as well as serving as a worthwhile contribution to the emerging body of scholarly writing on Web-based education for adult students.

Recommendations for Further Research

The following is a list of possible future research activities that could build on the strengths of this project, serve to further validate the findings, and expand the scope and reach of the investigation:

- An ethnographic study that evaluates concerns similar to the present study but evaluates adult learners over a longer period of time in a more authentic learning environment. This study could illuminate possible differences between the reactions of students using the Web in a limited, short-term capacity and the of responses of students more involved in the use of the technology over the period of a whole semester or year.

- It is also recommended that the relationship between the characteristics of learning styles with navigation styles be investigated as this particular aspect of the test phenomena raised some interesting issues but needs additional study to more fully understand the impact of these connections on adult learners.

- A study that poses similar questions to the current investigation but uses refined instruments and testing procedures could return more consistent results and could minimize anomalies that were identified in the current data. This is discussed in the Limitations and Improvements to Test Procedures section of this paper.

- Another study of adult learners in different life stages and/or less formal educational settings may reveal another perspective on the test phenomena that could add additional insight into the emerging challenges facing adults when using Web-based technology to facilitate their learning. In my view, life stage and educational setting are important distinctions that, with further investigation, may prove to be significant factors in both the motivation and success of adult students interacting with technology and in the design of education programs employing Web-based educational resources.

- Additional study of the incongruous patterns of connections between self-efficacy, success, and overall satisfaction of subjects with their test experience and the test Web sites. This point was identified as a 'curious corollary' in the study but requires further investigation to be fully understood. A study of this type could help to explain the reasons for the pattern of high scores on the subjective satisfaction questions and low performance on test tasks that was identified in this study. Refined testing procedures and instrumentation may also affect the factors in a test of this type.

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Appendix A: Kolb Learning Style Indicator (LSI 2)

This instrument is designed to assess your general learning style preferences and tendencies. Read each statement carefully. To the left of each statement, write the code that best describes how each statement applies to you. Answer honestly as there are no correct or incorrect answers.

SECTION 1: Place either an AE or a RO next to the statement below, depending upon which part of the statement mostly closely describes you.

1. _____ (**AE**) - I often produce off-the-cuff ideas that at first might seem silly or half-baked. (**RO**) - I am thorough and methodical.
2. _____ (**AE**) - I am normally the one who initiates conversations. (**RO**) - I enjoy watching people.
3. _____ (**AE**) - I am flexible and open-minded. (**RO**) - I am careful and cautious.
4. _____ (**AE**) - I like to try new and different things without too much preparation. (**RO**) - I investigate a new topic or process in depth before trying it.
5. _____ (**AE**) - I am happy to have a go at new things. (**RO**) - I draw up lists up possible courses of actions when starting a new project.
6. _____ (**AE**) - I like to get involved and to participate. (**RO**) - I like to read and observe.
7. _____ (**AE**) - I am loud and outgoing. (**RO**) - I am quite and somewhat shy.
8. _____ (**AE**) - I make quick and bold decisions. (**RO**) - I make cautious and logical decisions.
9. _____ (**AE**) - I speak slowly, after thinking. (**RO**) - I speak fast, while thinking.

Total of **AE**s - _____. Total of **RO**s - _____. The one that has the larger number is your task preference.

SECTION 2: Place either an AC or a CE next to the statement below, depending upon which part of the statement mostly closely describes you.

1. _____ (**AC**) - I ask probing questions when learning a new subject. (**CE**) - I am good at picking up hints and techniques from other people.
2. _____ (**AC**) - I am rational and logical. (**CE**) - I am practical and down to earth.
3. _____ (**AC**) - I plan events down to the last detail. (**CE**) - I like realistic, but flexible plans.
4. _____ (**AC**) - I like to know the right answers before trying something new. (**CE**) - I try things out by practicing to see if they work.
5. _____ (**AC**) - I analyze reports to find the basic assumptions and inconsistencies. (**CE**) - I rely upon others to give me the basic gist of reports.
6. _____ (**AC**) - I prefer working alone. (**CE**) - I enjoy working with others.
7. _____ (**AC**) - Others would describe me as serious, reserved, and formal. (**CE**) - Others would describe me as verbal, expressive, and informal.
8. _____ (**AC**) - I use facts to make decisions. (**CE**) - I use feelings to make decisions.
9. _____ (**AC**) - I am difficult to get to know. (**CE**) - I am easy to get to know.

Total of **AC**s - _____. Total of **CE**s - _____. The one that has the larger number is your thought or emotional preference.

SCORING PROCEDURES

Each preference (high score) from the two above sections are used to determine your learning style:

- If you are a RO and CE then you are a **Watcher**: Reflective *Observation* & *Concrete Experience*
- If you are a AE and CE then you are a **Doer:** *Concrete Experience* & *Active Experimentation*
- If you are a RO and AC then you are a **Thinker**: Abstract *Conceptualization & Reflective Observation*
- If you are a AE and AC then you are a **Feeler**: Abstract *Conceptualization* & *Active Experimentation*

Note that individuals learn in **ALL** four styles, but one typically learns best by starting in and using one style the most.

Appendix B: Eachus and Cassidy Computer User Self-Efficacy Scale

The purpose of this questionnaire is to examine the benefits and difficulties people experience when using computers. The questionnaire is divided into two parts. In Part 1 you are asked to provide some basic background information about yourself and your experience of computers, if any. Part 2 aims to elicit more detailed information by asking you to indicate the extent to which you agree or disagree with a number of statements provided.

Part 1:
Your age? **Your gender?**

What do you consider your experience with computers?:
None Very limited Some experience Quite a lot Extensive

Please indicate the computer packages (software) you have used [circle all that apply]:

Word-processing	Spreadsheets	Databases	Graphics/Presentation
Statistical Analysis	Desktop publishing	Multimedia	Other (specify)

Do you own a computer? Yes no

Do you have access to a computer when you are not at school or at work? Yes no

Have you ever attended a computer-training course? Yes no

Part 2
Below you will find a number of statements concerning how you might feel about computers. Please indicate the strength of your agreement/disagreement with the statements using the six point scale shown below where 1= strong disagreement and 6= strong agreement with a particular statement. There are no 'correct ' responses, it is your own views that are important. It will take you only a few minutes to complete the thirty statements that make up the questionnaire, but it is important that you respond to each statement.

Strongly Disagree 1 2 3 4 5 6 Strongly Agree
1. Most difficulties I encounter when using computers, I can usually deal with.
2. I find working with computers very easy.
3. I am very unsure of my abilities to use computers.
4. I seem to have difficulties with most of the packages I have tried to use
5. Computers frighten me.
6. I enjoy working with computers.
7. I find computers get in the way of learning.
8. DOS-based [command line interface] computer packages don't cause many problems for me.
9. Computers make me much more productive.
10. I often have difficulties when trying to learn how to use a new computer package.
11. Most of the computer packages I have had experience with, have been easy to use.
12. I am very confident in my abilities to use computers.
13. I find it difficult to get computers to do what I want them to.
14. At times I find working with computers very confusing.
15. I would rather that we did not have to learn how to use computers.
16. I usually find it easy to learn how to use a new software package.
17. I seem to waste a lot of time struggling with computers.
18. Using computers makes learning more interesting.
19. I always seem to have problems when trying to use computers.
20. Some computer packages definitely make learning easier.
21. Computer jargon baffles me.
22. Computers are far too complicated for me.
23. Using computers is something I rarely enjoy.
24. Computers are good aids to learning.
25. Sometimes, when using a computer, things seem to happen and I don't know why.
26. As far as computers go, I don't consider myself to be very competent.
27. Computers help me to save a lot of time.

28. I find working with computers very frustrating.
29. I consider myself a skilled computer user.
30. When using computers I worry that I might press the wrong button and damage it.

Scoring of the Computer Self-Efficacy Scale "Student Attitude towards Computers"
Part 1: Experience with computers - this question is scored using a standard Likert format where "none" is scored as 1 and "extensive" is scored as 5. “Number of computer packages used” - here the respondent is scored 1 for each package used and these are totaled to give a score for the question, i.e. total number of packages used.

Part 2: Items 1 to 30 are all scored on a six point Likert scale. Items 1, 2, 6, 8, 9, 11, 12, 16, 18, 20, 24, 27 and 29 are positively worded and the respondent's response is recorded as the actual scale score for these items, e.g. a response of 4 to item 1 will be scored as 4, i.e. Strongly Disagree 1 2 3 4 5 6 Strongly Agree. Items 3, 4, 5, 7, 10, 13, 14, 15, 17, 19, 21, 22, 23, 25, 26, 28 and 30 are negatively worded and are scored in reverse, i.e. Strongly Agree 1 2 3 4 5 6 Strongly Disagree.

A scale score for these items is obtained by subtracting the respondent's response from 7, e.g. a response of 4 to item 3 will be scored as 3. Summing the scores for all 30 items gives a self-efficacy score and by scoring the scale in such a way, high scale scores indicate greater confidence for computer use.

Appendix C: Felder / Silverman Index of Learning Styles

Directions: Circle **(a)** or **(b)** to indicate your answer to every question. Choose only one answer for each question.

If both **(a)** and **(b)** seem to apply to you, choose the **one** that applies more frequently.

1. I understand something better after I
   (a) try it out. **(b)** think it through.

2. I would rather be considered
   (a) realistic. **(b)** innovative.

3. When I think about what I did yesterday, I am most likely to get
   (a) a picture. **(b)** words.

4. I tend to
   (a) understand details of a subject but may be fuzzy about its overall structure.
   (b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to
   (a) talk about it. **(b)** think about it.

6. If I were a teacher, I would rather teach a course
   (a) that deals with facts and real life situations. **(b)** that deals with ideas and theories.

7. I prefer to get new information in
   (a) pictures, diagrams, graphs, or maps. **(b)** written directions or verbal information.

8. Once I understand
   (a) all the parts, I understand the whole thing. **(b)** the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to
   (a) jump in and contribute ideas. **(b)** sit back and listen.

10. I find it easier
    (a) to learn facts. **(b)** to learn concepts.

11. In a book with lots of pictures and charts, I am likely to
    (a) look over the pictures and charts carefully. **(b)** focus on the written text.

12. When I solve math problems
    (a) I usually work my way to the solutions one step at a time.
    (b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken
    (a) I have usually gotten to know many of the students.
    (b) I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer
    (a) something that teaches me new facts or tells me how to do something.
    (b) something that gives me new ideas to think about.

15. I like teachers
    (a) who put a lot of diagrams on the board. **(b)** who spend a lot of time explaining.

16. When I'm analyzing a story or a novel
    (a) I think of the incidents and try to put them together to figure out the themes.

(b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to
(a) start working on the solution immediately. **(b)** try to fully understand the problem first.

18. I prefer the idea of
(a) certainty. **(b)** theory.

19. I remember best
(a) what I see. **(b)** what I hear.

20. It is more important to me that an instructor
(a) lay out the material in clear sequential steps. **(b)** give me an overall picture and relate the material to other subjects.

21. I prefer to study
(a) in a study group. **(b)** alone.

22. I am more likely to be considered
(a) careful about the details of my work. **(b)** creative about how to do my work.

23. When I get directions to a new place, I prefer
(a) a map. **(b)** written instructions.

24. I learn
(a) at a fairly regular pace. If I study hard, I'll "get it." **(b)** in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first
(a) try things out. **(b)** think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to
(a) clearly say what they mean. **(b)** say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember
(a) the picture. **(b)** what the instructor said about it.

28. When considering a body of information, I am more likely to
(a) focus on details and miss the big picture. **(b)** try to understand the big picture before getting into the details.

29. I more easily remember
(a) something I have done. **(b)** something I have thought a lot about.

30. When I have to perform a task, I prefer to
(a) master one way of doing it. **(b)** come up with new ways of doing it.

31. When someone is showing me data, I prefer
(a) charts or graphs. **(b)** text summarizing the results.

32. When writing a paper, I am more likely to
(a) work on (think about or write) the beginning of the paper and progress forward.
(b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to
(a) have "group brainstorming" where everyone contributes ideas.
(b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone
(a) sensible. **(b)** imaginative.
35. When I meet people at a party, I am more likely to remember
(a) what they looked like. **(b)** what they said about themselves.

36. When I am learning a new subject, I prefer to
(a) stay focused on that subject, learning as much about it as I can.
(b) try to make connections between that subject and related subjects.

37. I am more likely to be considered
(a) outgoing. **(b)** reserved.

38. I prefer courses that emphasize
(a) concrete material (facts, data). **(b)** abstract material (concepts, theories).

39. For entertainment, I would rather
(a) watch television. **(b)** read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
(a) somewhat helpful to me. **(b)** very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,
(a) appeals to me. **(b)** does not appeal to me.

42. When I am doing long calculations,
(a) I tend to repeat all my steps and check my work carefully.
(b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been
(a) easily and fairly accurately. **(b)** with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to
(a) think of the steps in the solution process.
(b) think of possible consequences or applications of the solution in a wide range of areas.

[Also available on-line - http://www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/ilsWeb.html]

Appendix D: Web Usability Interface Element Checklist

Instructions: use this checklist to keep track of the interface elements used by the learner while interacting with the test Web sites. Place a check mark next to the element each time it is used by the test subject. Keep a cumulative list for all of the sites tested by the learner; there is no need to make a separate list for each Web site. Remember to remind the learner to use the 'thinking aloud method' to talk through their browsing and navigation actions.

Graphic, interface, navigation, and multimedia elements Checklist:	
Web Browser Elements:	
Browser address fields	
Browser buttons/icons	
Browser menus	
Scroll bars	
Web Page Elements:	
Drop-down menus	
Graphics	
Help/instructions	
Icons / Buttons	
Image maps	
Index	
In-text hyperlinks	
Input fields	
Multimedia [Audio/Video]	
Navigation bars/buttons	
Plug-ins	
Search features	
Site maps	
Text	

Additional Notes:

Appendix E: Subjective Satisfaction Interview Questionnaire

Complete the following questions in response to your experiences using the Web-based educational resources in this exercise. For each question, please circle the number corresponding to your answer or complete the answer in your own words.

1) Rate the difficulty of the **set of tasks** you were asked to perform (Circle one):

	(Difficult)				(Easy)
Task A	1	2	3	4	5
Task B	1	2	3	4	5

2) How easy or difficult was it for you to **navigate** the Web site (s) you were using for this experiment?
(Difficult) (Easy)
1 2 3 4 5

3) How well **organized** was the Web site (s) you were using?
(Poor) (Excellent)
1 2 3 4 5

4) What was the **most helpful or useful** element of the design of the Web site?

5) What was the most **aesthetically pleasing** element of the design of the Web site?

6) Did you prefer to navigate through the site mainly using **text links**, or **graphic icons**?

7) How useful was the design of the interface in helping you **find the information** you were looking for?
(Not useful) (Very useful)
1 2 3 4 5

8) Overall, how **satisfied** were you with the Web sites?
(Not satisfied) (Very Satisfied)
1 2 3 4 5

9) What **experience** do you have using the Web in courses you have taken?

10) Please give any comments you have about your opinion of the Web sites used in the experiment. You may mention color, organization, design, language, or anything else that influenced your experience with these sites.

11) Is there anything else that you feel influenced (positively or negatively) your opinion, success or satisfaction with these Web sites – such as your ability using computers, your educational or professional experience or any other personal factors?

Appendix F: Sample Usability Task Scenarios

Scenario 1: You are a graduate student working in the area of educational technology and need to do research on Web-based learning. Complete the following tasks from the test Web sites. Use the 'thinking aloud' method to describe your actions to the test observer as you navigate and search for information on the sites.

Web site 1: EDUC533: Virtual Learning for Staff Development
[http://Webct.drexel.edu/SCRIPT/EDUC533/scripts/serve_home]
Task A: Log-in to the course site and check to see what the requirements are for the assignment titled 'Reflection #4.' When is this due?

Web site 2: Ask ERIC research database – http://www.askeric.org/
Task B: Log-in to the Drexel University Library Electronic Resources site and access the ERIC database. Find articles with the keywords "usability" AND "adult" AND "Web." How many full text articles are available?

Scenario 2: You are an education major at Drexel University getting ready for your student teaching experience. Your professor suggests that you use the Web to find resources that might be helpful in preparing you for the classroom. With this in mind, please try to complete the following tasks.

Website 1: TeacherNet [www.teachernet.com],
Task A: Using the TeacherNet Website [www.teachernet.com], find information on "planning a unit of instruction" for student teachers. Can you find anything on this site on this topic? If so, are there any related links to national educational standards included?

Task B: Using the TeacherNet Website [www.teachernet.com], follow the link to 'River Deep Interactive Learning' listed in the Technology Resource Links section and check to see if they have any sample interactive lessons you might use in your science classroom.

Scenario 3: You are a student at Drexel University taking a class on the History and Philosophy of Mathematics. Dr. Bach has asked you to use the Fractals site he designed to help with your study in the course. With this in mind, please try to complete the following tasks.

Website 1: Dr. Bach's Fractals site [http://www.pages.drexel.edu/~bachcn/Fractals/index.htm]
Task A: Navigate to the site and go to lesson 1 section IV 'Fractals and Human Creations.' View the text descriptions and graphic animations on exploring man-made fractals and the fractal properties of human creations. Do the animations help you see the underlying fractal patterns in the photographs?

Web site 2: ERIC Information site [http://www.askeric.org/]
Task B: Navigate to the AskEric.org site. Search the ERIC database to find journal articles with the keywords "history" AND "Philosophy" AND "Mathematics" written in the past 5 years. How many articles are available?

Web site 3: Development Online Mentoring Guide [http://Webctdev.irt.drexel.edu:8080]
Task A: Log-in to the demo mentoring site and check to see if there are any new students to respond to. Go through the steps you would normally take to answer a student question.

Appendix G: Test Subject Informed Consent Form

Research Project Title: An Investigation of the Connections Between Adult Student Success, Satisfaction, and Learning Preferences and Usable Interface Design of Web-Based Educational Resources

Investigators: Dr. Craig N. Bach, Mr. Jason E. Rollins

Please take the time to read this form carefully and to understand any accompanying information. This research study is concerned with factors that affect adult student success and satisfaction with their use of Web-based educational resources and is being conducted as part of a Ph.D. dissertation course of study in the School of Education, Drexel University, Philadelphia, Pennsylvania.

The study will require approximately one hour of your time during which you will be asked to: (1) complete several tasks using a computer to navigate an educational Web site; (2) complete several surveys relating to your learning preferences and attitude toward using computers; (3) answer a few interview questions about your experience using the Web for educational purposes and your experience in this study. Your responses, along with those of approximately 75 other students will be collected in connection with the dissertation study.

All of the information we collect from you will be stored so that your name is not associated with it (using an arbitrary participant number). The write-up of the data will not include any information that can be linked directly to you. The research materials will be stored with complete security throughout the entire investigation.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a test subject. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to not answer specific items or questions in interviews or on questionnaires. You are free to withdraw from the study at any time without penalty. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

Dr. Craig N. Bach, Assistant Professor, School of Education, Drexel University
Mr. Jason E. Rollins, PhD Candidate, School of Education, Drexel University

Participant: Date:

Investigator: Date:

A copy of this consent form is available for you to keep for your records and reference. This research has the approval of the Institutional Review Board (IRB) of Drexel University.

Appendix H: Screen Shots of Test Web Sites

Website 1: Ask Eric (www.askeric.org). This site is a government run and funded educational research database site that uses a mix of graphic designs and text-based elements in presenting content and framing and explaining a powerful search engine, which is the site's primary feature. The site organization and navigation structure is relatively simple and flat and serves primary to frame the search feature. This site is widely used by education students and professional researchers as a search portal. Student test subject were asked to navigate to the search page and then perform a specific search with several parameters. Test subject were then asked specific questions about the search results. Details of these tasks are listed in Appendix F: Sample Usability Task Scenarios.

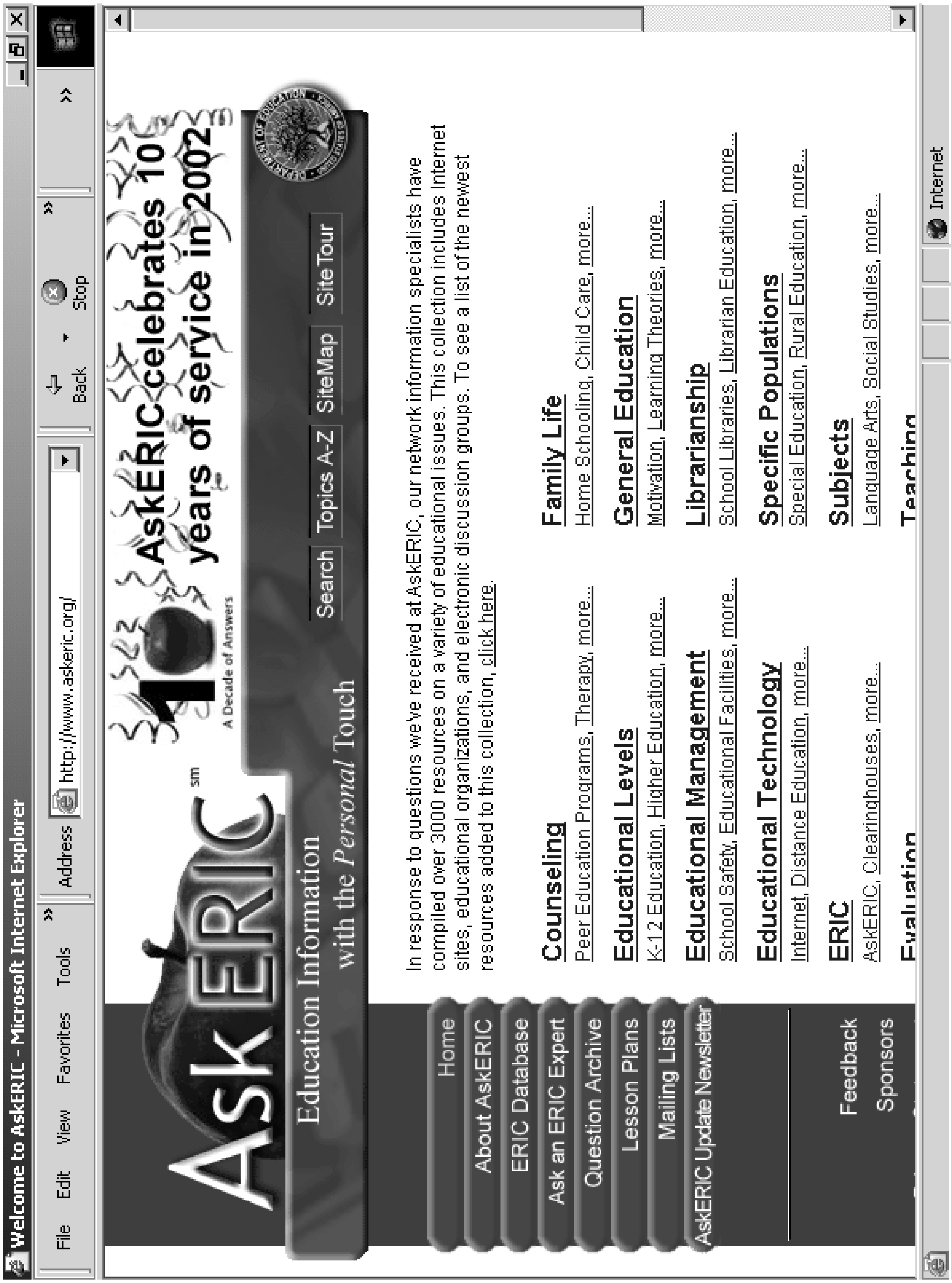

Figure 7 Screen shot of Web site 1 - Ask Eric

Website 2: A Fractal Is a Pattern in Your Neighborhood (http://www.pages.drexel.edu/~bachcn/Fractals/index.htm). This site was created by Drexel University staff for a science and math teacher-training program. The site is graphically intense and includes many types of multi-media. The site navigation and organization structure is narrow and shallow. The site is used by teachers and trainers involved in a joint program of The School District of Philadelphia and Drexel University. Test subjects were asked to navigate to an area of the site and compare several presentations of the same course material. Test subjects were then asked specific questions about the organization and multi-media elements of the site. Details of these tasks are listed in Appendix F: Sample Usability Task Scenarios.

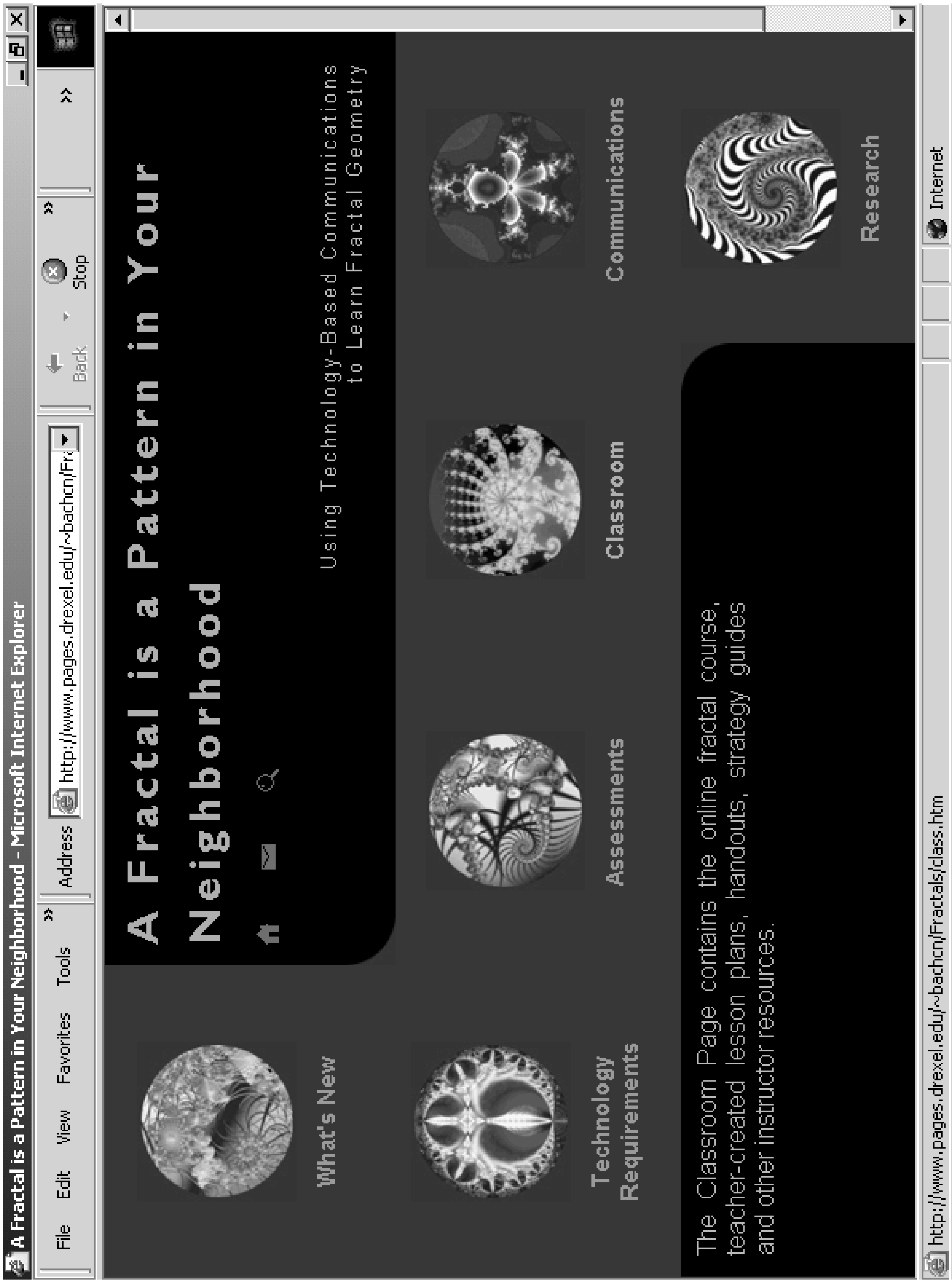

Figure 8 Screen shot of Web site 2 - A Fractal Is a Pattern in Your Neighborhood

Website 3: TeacherNet (www.teachernet.com). This site is a commercially run information portal for professional K-8 educators and student teachers. This site is both graphically intense and rich in media and text content; it is a professionally designed site that contained hundreds of pages. This site's navigation is both broad and deep and facilitates multi entry points to content and search features. This site is commonly used by teachers and teachers-in-training to research, download, and purchase classroom instructional material. Test subjects were asked to search for specific site content and then asked directed questions about the text and graphic presentation of the material. Details of these tasks are listed in Appendix F: Sample Usability Task Scenarios.

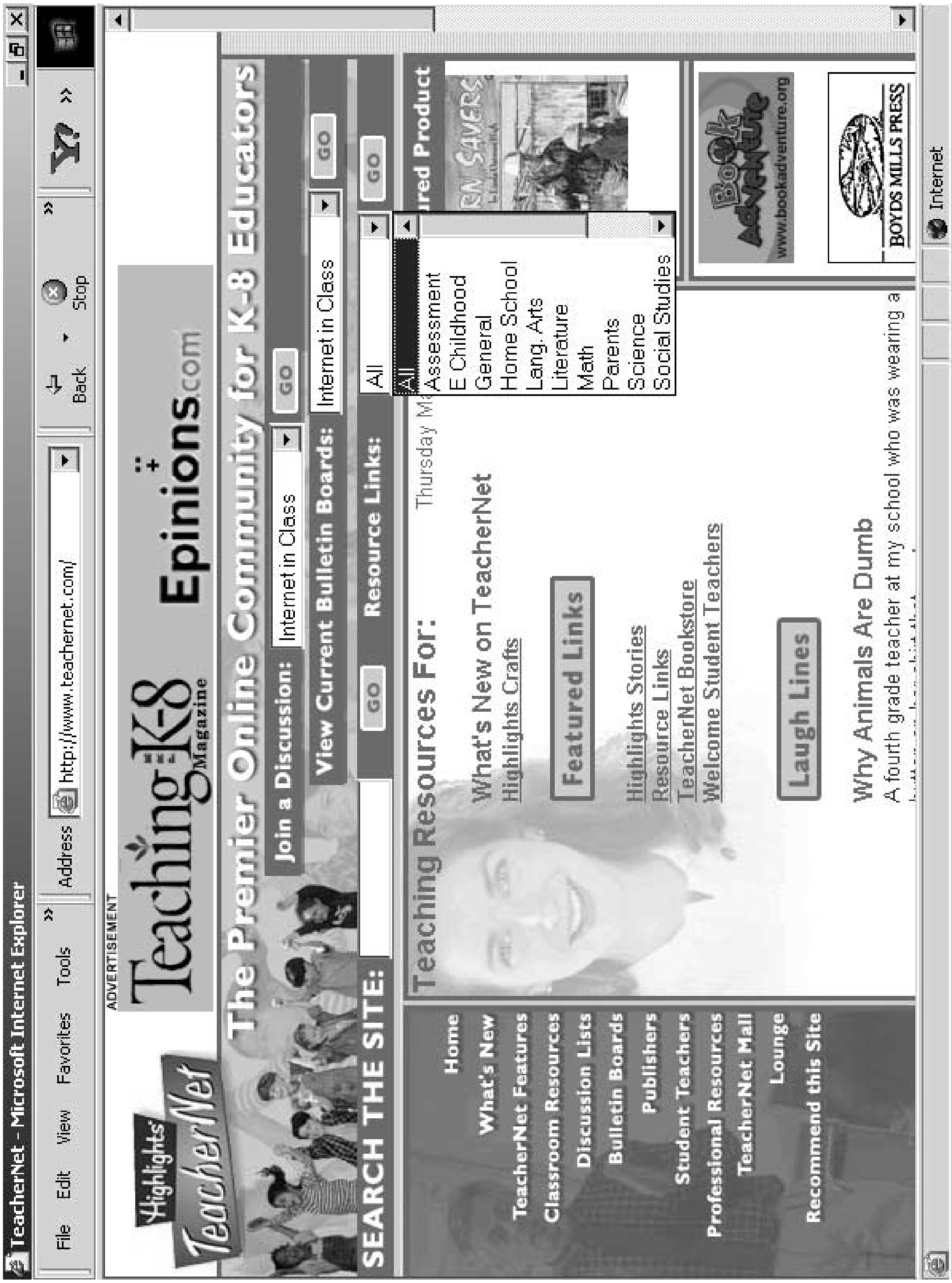

Figure 9 Screen shot of Web site 3 - TeacherNet

Website 4: WebCT Online Mentoring Guide Course (http://Webct.dev.irt.drexel.edu:8080/ol). This site is an on-line component to a face-to-face course on mathematics education. The site was designed and hosted using the popular, commercial on-line course development environment called *WebCT*. The site navigation structure is relatively flat with many navigation choices leading to content sections that are shallow, usually only one or two levels deep. This site is used by students enrolled in the face-to-face course as a training module for several required course assignments. Test subjects were asked to complete several searching and entering tasks and then asked to answer questions about their interaction with the site. Details of these tasks are listed in Appendix F: Sample Usability Task Scenarios.

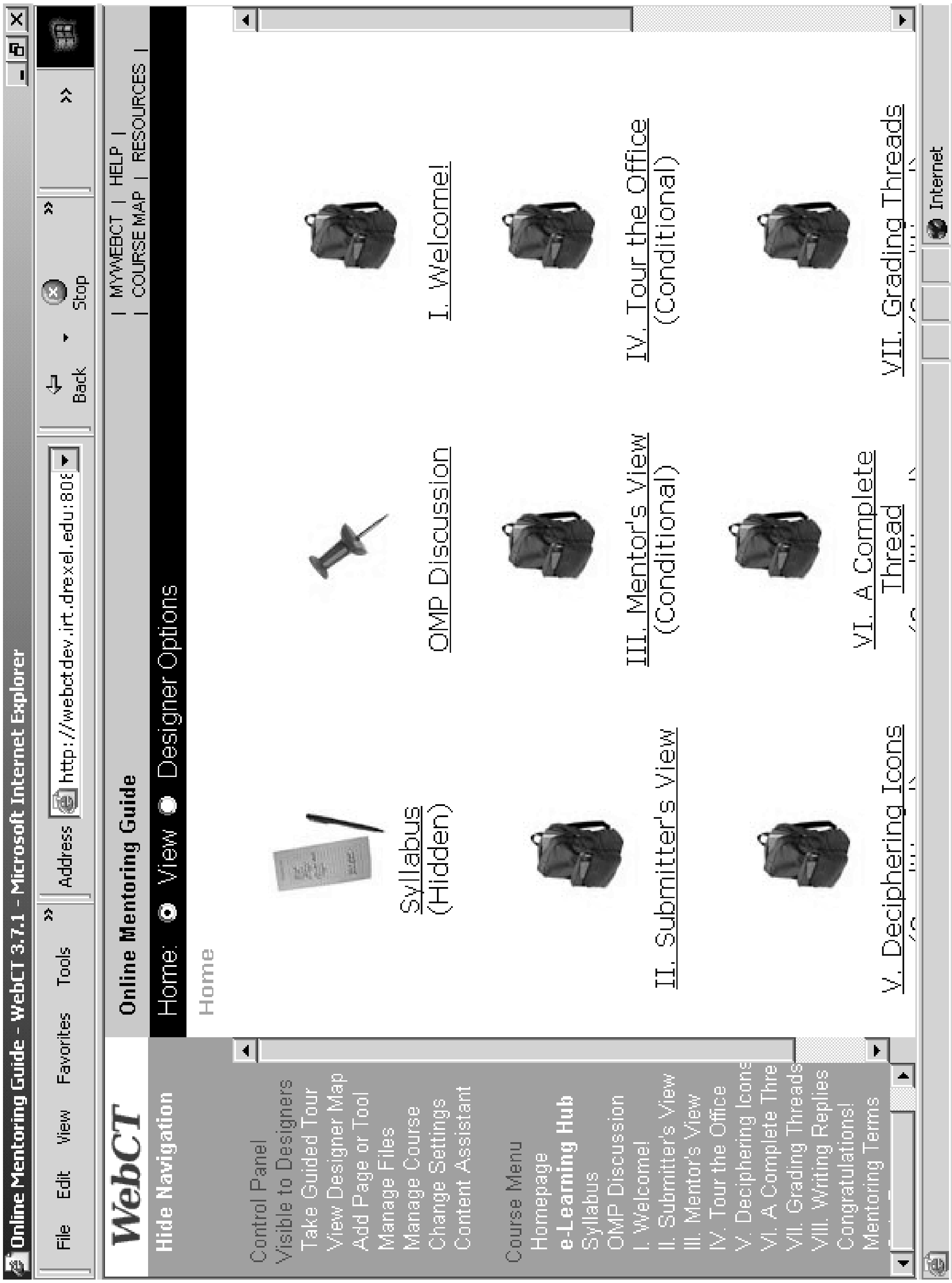

Figure 10 Screen shot of Web site 4 - WebCT Online Mentoring Guide Course

Appendix I: Research Data Tables and Figures

Table 7 Research Data

Sub	Kolb Type	REFACT	SENINT	VISVRB	SEQGLO	Proportion of Graphic Actions	Graphic Actions	Text Actions	Total Actions	Eachus	Easy	Satisfied
1	1	REF1	SEN1	VRB1	SEQ1	0.53	21	19	40	152	4	5
2	3	ACT1	SEN1	VIS2	GLO1	0.64	23	13	36	158	4	5
3	2	ACT2	SEN1	VRB3	GLO1	0.38	15	24	39	183	4	5
4	4	ACT3	SEN1	VRB3	SEQ1	0.24	9	28	37	127	3	3
5	2	REF1	INT1	VIS2	GLO3	0.34	10	19	29	122	3	3
6	3	REF1	INT3	VIS3	GLO3	0.61	25	16	41	152	4	4
7	4	ACT3	INT1	VIS2	SEQ1	0.33	7	14	21	158	4	5
8	4	ACT2	SEN1	VRB3	GLO1	0.23	6	20	26	160	4	5
9	4	ACT3	SEN1	VRB3	SEQ2	0.26	12	35	47	158	3	4
10	4	ACT2	INT1	VIS3	GLO1	0.64	18	10	28	158	3	4
11	3	ACT2	SEN3	VIS3	SEQ2	0.69	24	11	35	160	4	4
12	3	ACT1	INT1	VIS1	GLO2	0.49	18	19	37	160	5	4
13	4	ACT2	INT1	VIS3	GLO1	0.61	25	16	41	161	5	5
14	4	REF1	SEN2	VIS1	SEQ1	0.47	18	20	38	146	3	3
15	2	REF1	SEN1	VIS3	SEQ1	0.69	24	11	35	150	3	3
16	1	ACT3	INT1	VRB3	GLO1	0.29	10	24	34	188	4	4
17	2	ACT2	SEN1	VRB2	SEQ2	0.42	16	22	38	143	3	3
18	3	ACT3	SEN1	VRB1	SEQ2	0.41	12	17	29	152	5	4
19	3	REF1	SEN1	VRB1	SEQ1	0.49	18	19	37	119	3	4
20	1	ACT1	SEN1	VIS2	GLO1	0.45	18	22	40	183	5	4
21	2	ACT2	SEN1	VRB3	GLO1	0.44	24	31	55	152	4	4
22	4	REF1	SEN1	VIS3	SEQ2	0.6	30	20	50	123	4	4
23	4	REF1	SEN1	VRB1	SEQ1	0.42	15	21	36	183	5	5
24	1	REF1	SEN1	VIS3	GLO3	0.6	33	22	55	148	4	5
25	4	REF1	SEN1	VRB1	SEQ1	0.47	21	24	45	178	3	4
26	4	REF1	SEN1	VRB1	SEQ1	0.42	19	26	45	145	3	5
27	3	ACT2	SEN1	VRB3	GLO1	0.39	20	31	51	125	3	4
28	4	ACT3	SEN1	VRB3	GLO1	0.41	15	22	37	188	3	4
29	4	REF1	INT3	VIS3	GLO3	0.58	23	17	40	161	5	4
30	3	REF1	SEN1	VRB1	SEQ1	0.44	18	23	41	176	4	5
31	4	ACT2	SEN1	VRB2	SEQ2	0.48	24	26	50	132	4	4
32	4	ACT3	SEN1	VIS3	GLO1	0.6	21	14	35	139	4	4
33	3	ACT2	SEN1	VRB3	GLO1	0.59	30	21	51	122	4	4
34	3	ACT3	SEN1	VRB3	SEQ2	0.39	18	28	46	134	4	4
35	4	REF1	INT3	VIS3	GLO3	0.55	21	17	38	140	4	4
36	4	REF1	SEN1	VRB1	SEQ1	0.61	14	9	23	165	4	2
37	2	ACT2	SEN1	VRB3	SEQ2	0.35	14	26	40	170	4	4
38	3	REF1	INT3	VIS3	GLO3	0.59	22	15	37	156	5	4
39	3	ACT3	INT1	VIS2	GLO1	0.42	18	25	43	149	2	4
40	4	ACT2	SEN1	VRB1	SEQ1	0.45	9	11	20	176	3	4
41	4	ACT3	SEN1	VIS3	GLO1	0.59	26	18	44	177	4	4
42	4	ACT2	INT1	VIS2	GLO1	0.37	19	32	51	169	4	4
43	2	ACT2	SEN1	VRB2	SEQ2	0.48	29	31	60	158	4	5

Table 7 continued

Sub	Kolb Type	REFACT	SENINT	VISVRB	SEQGLO	Proportion of Graphic Actions	Graphic Actions	Text Actions	Total Actions	Eachus	Easy	Satisfied
45	3	REF1	SEN1	VRB1	SEQ1	0.46	21	25	46	154	4	2
46	1	ACT1	SEN1	VIS2	GLO1	0.46	21	25	46	183	4	4
47	4	ACT2	SEN1	VRB3	GLO1	0.43	24	32	56	181	5	2
48	4	ACT3	INT1	VRB1	GLO1	0.46	21	25	46	152	2	5
49	3	ACT2	SEN1	VRB3	SEQ2	0.46	27	32	59	148	4	4
50	2	ACT3	SEN1	VRB1	SEQ2	0.46	21	25	46	152	4	4

The following figures illustrate relationships between various research data elements, and were used in the development of the final data analysis.

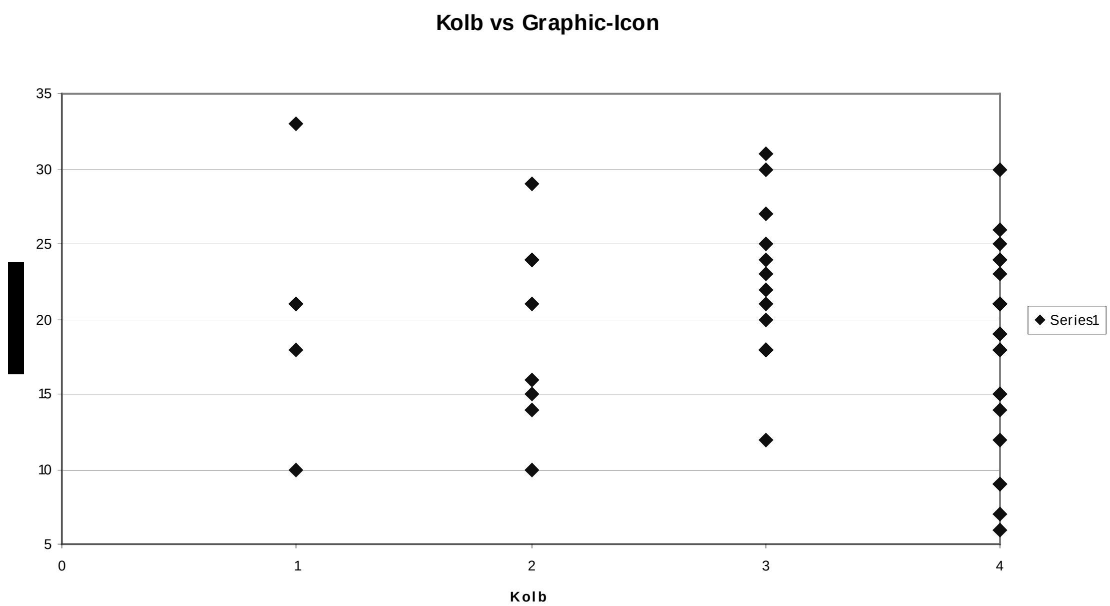

Figure 11 Kolb vs. Graphic Icon Use

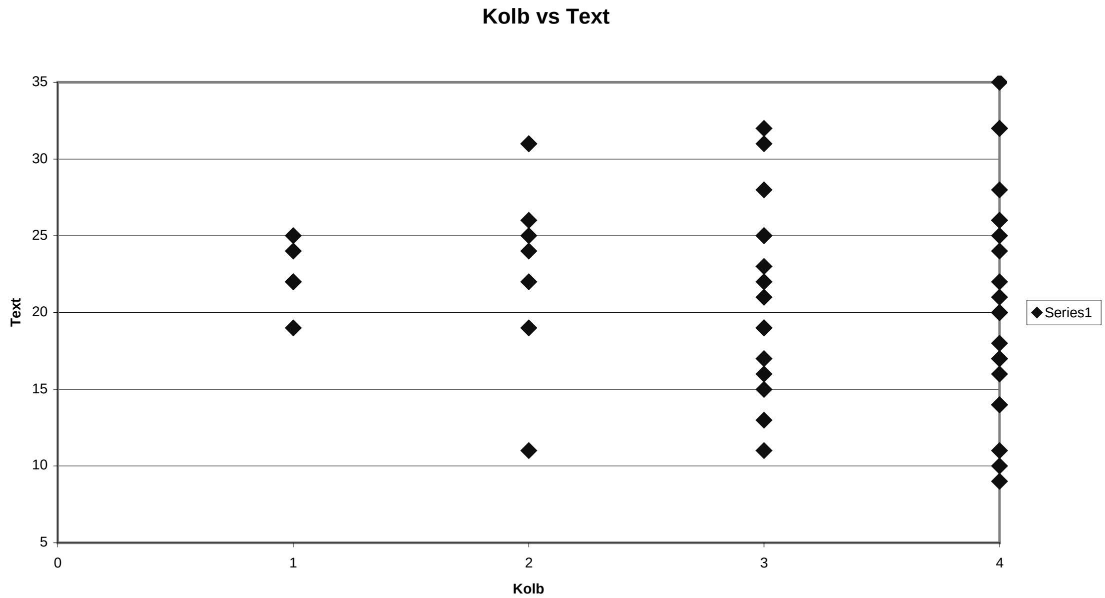

Figure 12 Kolb vs. Textual Element Use

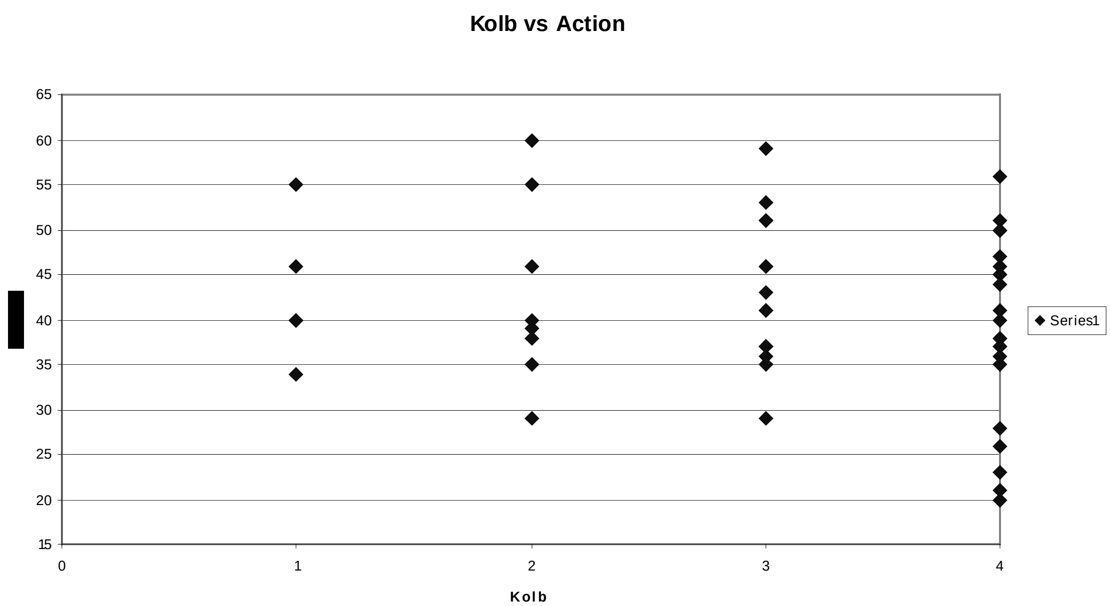

Figure 13 10 Kolb vs Total Actions (All Screen Elements)

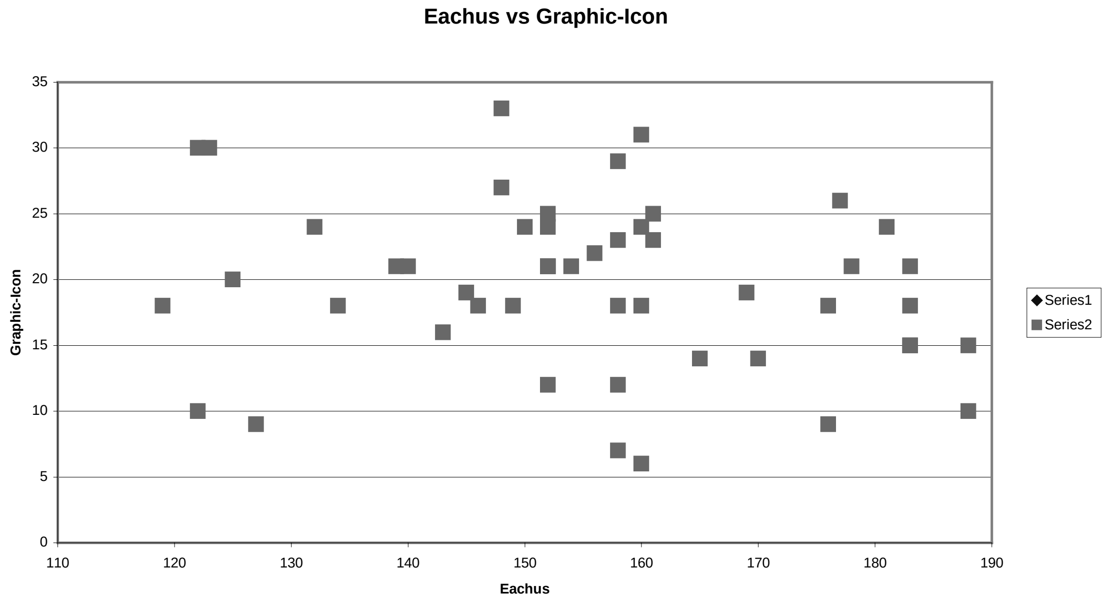

Figure 14 Eachus Cassidy vs. Graphic Icon Use

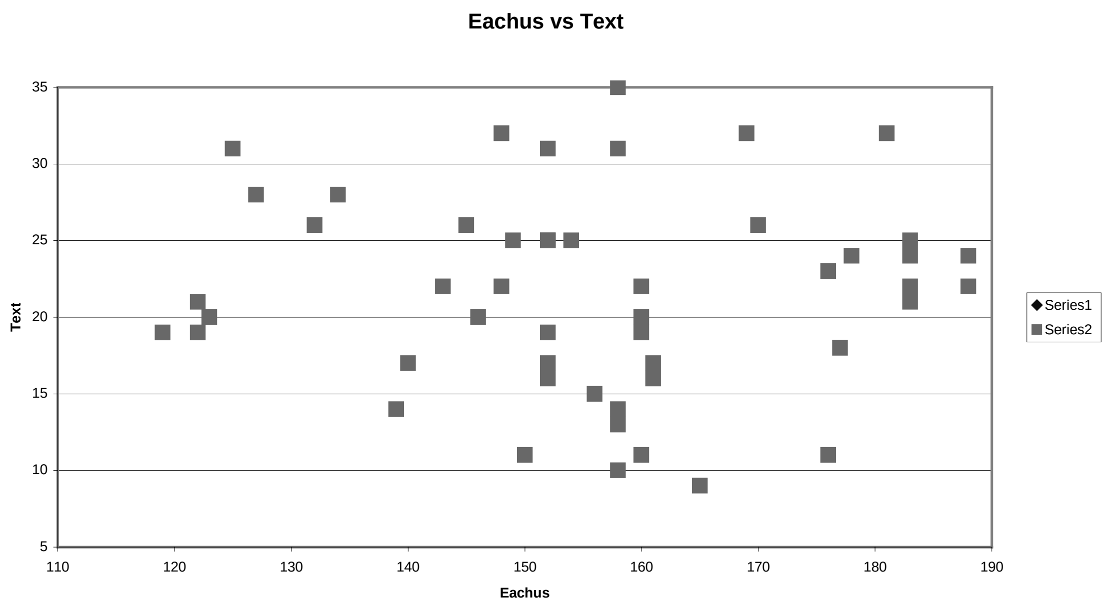

Figure 15 Eachus Cassidy vs. Text Element Use

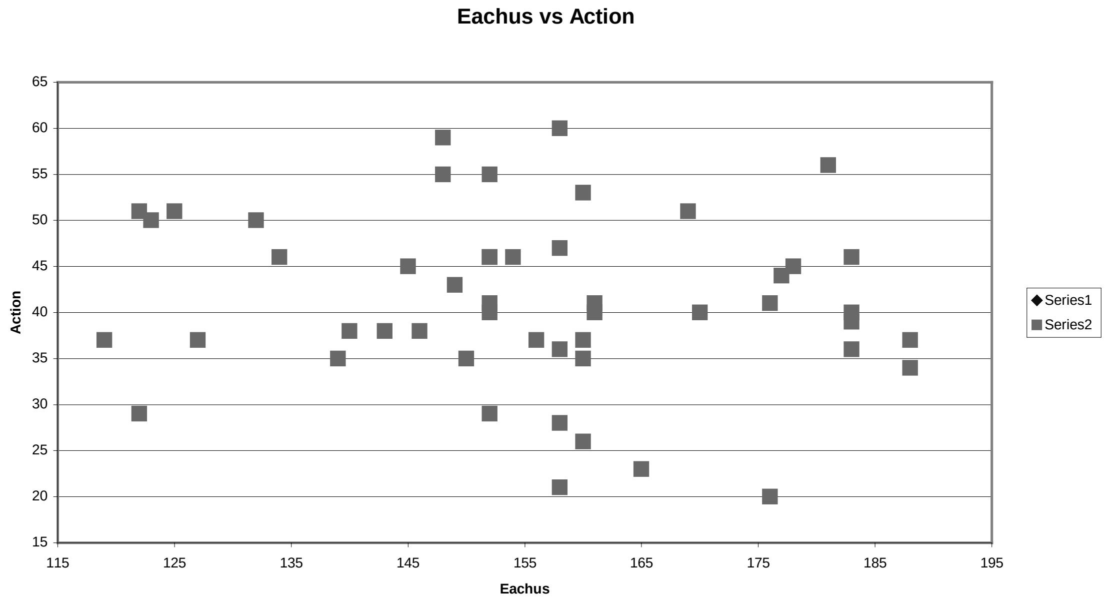

Figure 16 Eachus Cassidy vs. Total Actions (All Screen Elements)

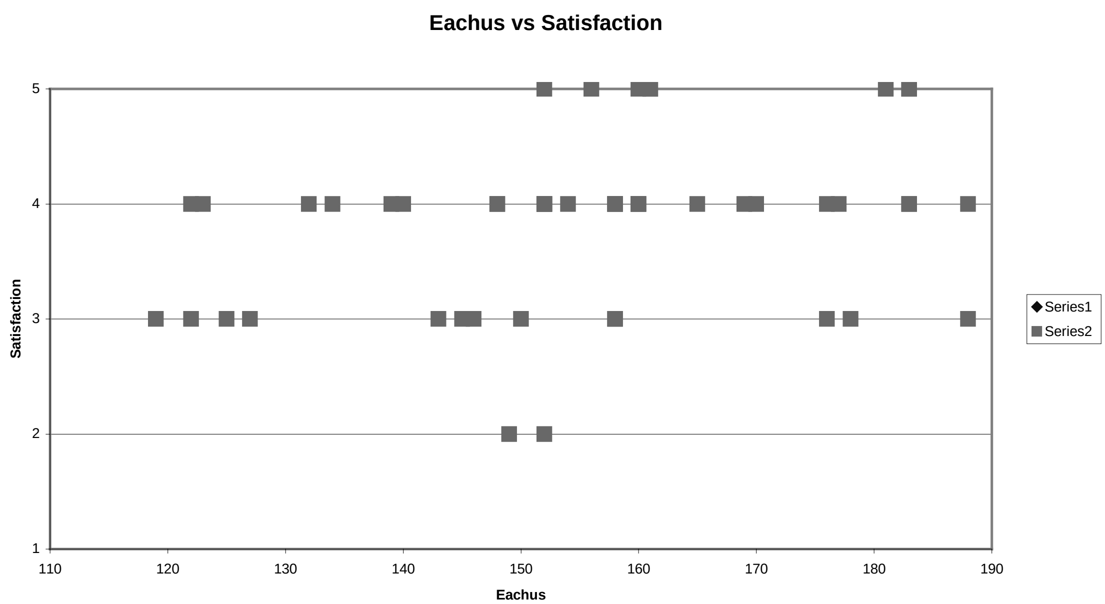

Figure 17 Eachus Cassidy vs. Satisfaction

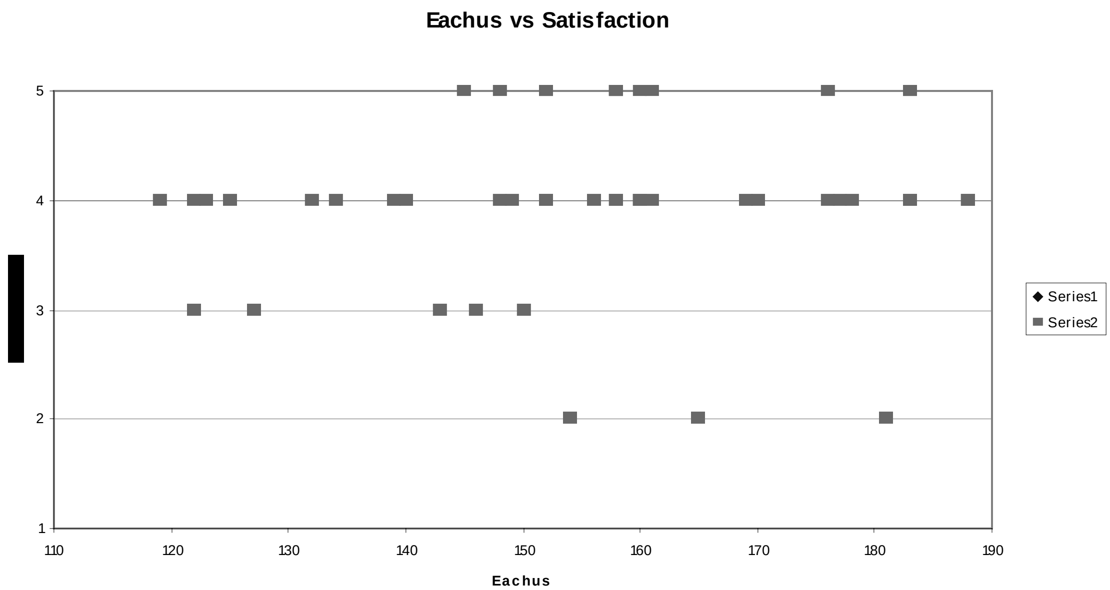

Figure 18 Eachus Cassidy vs. Satisfaction II

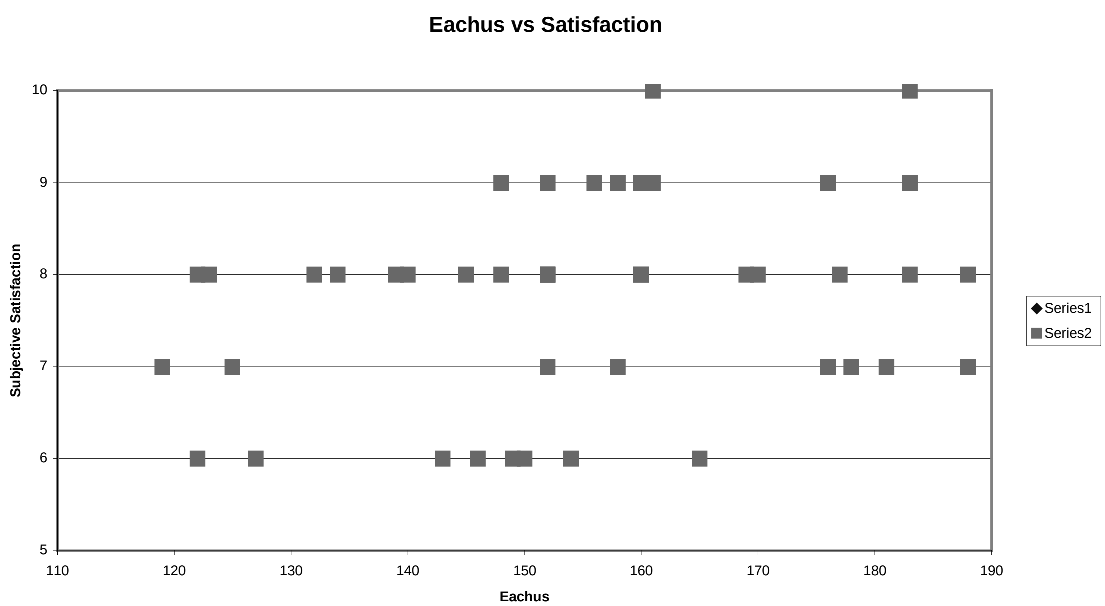

Figure 19 Eachus Cassidy vs. Total Subjective Satisfaction

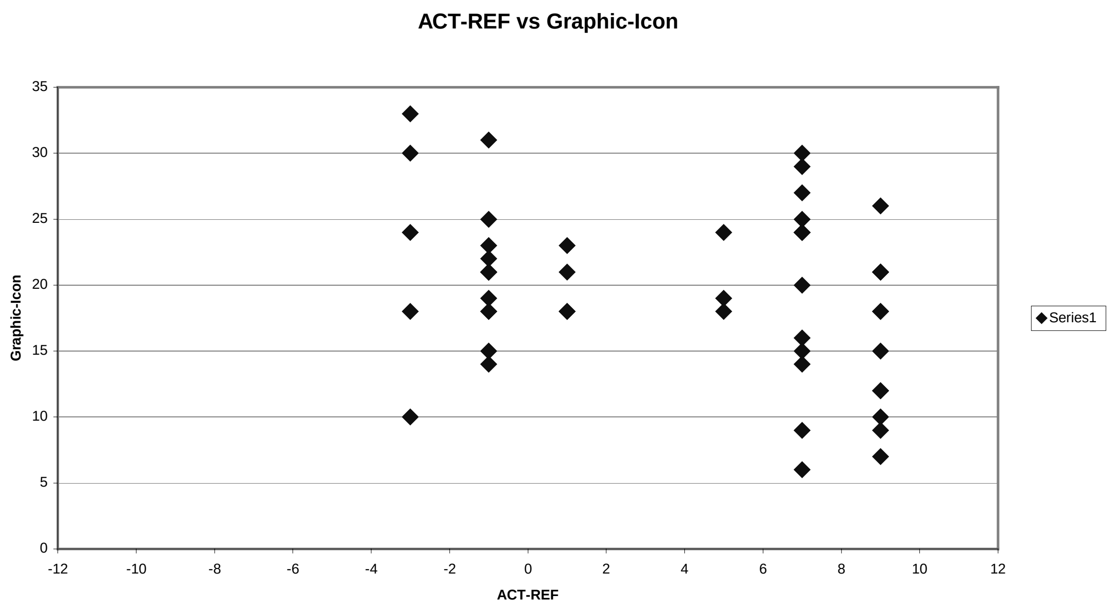

Figure 20 Act-Ref vs. Graphic Icon Use

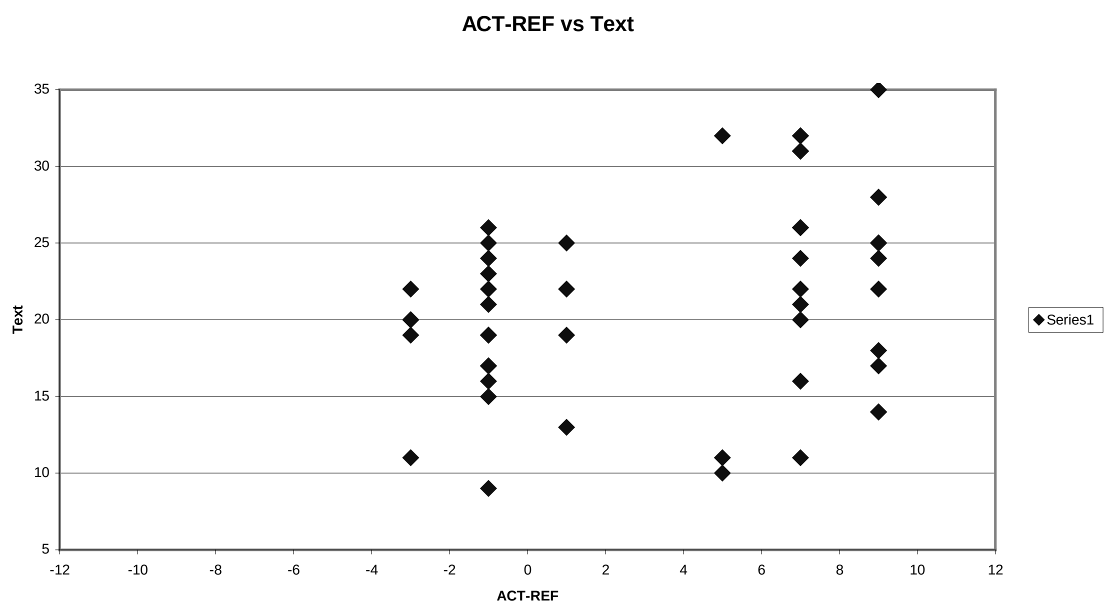

Figure 21 Act-Ref vs. Text Use

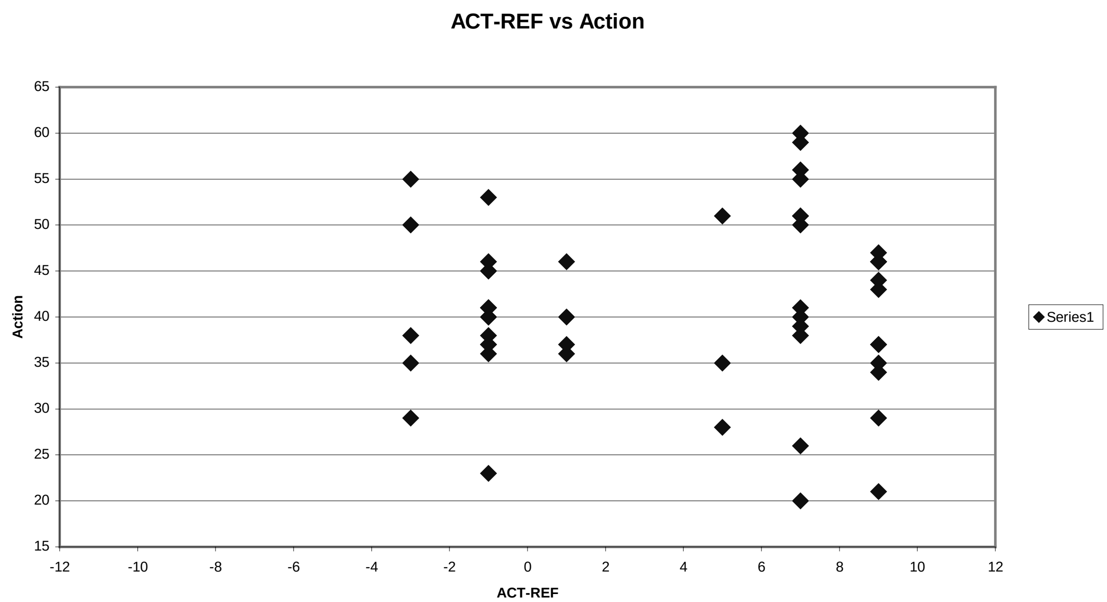

Figure 22 Act-Ref vs. Actions

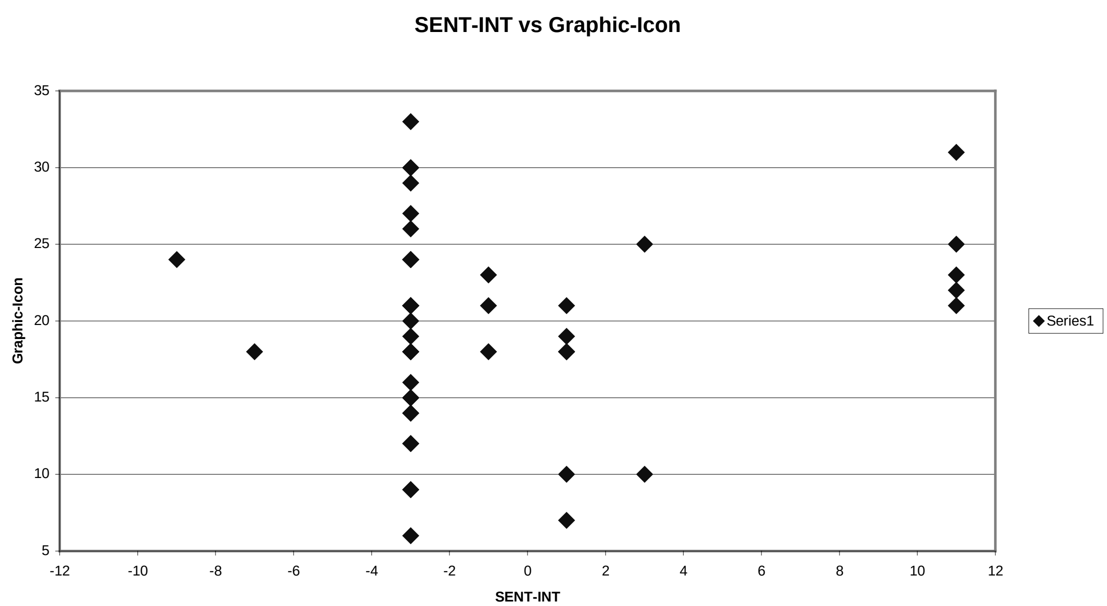

Figure 23 Sent-Int vs. Graphic Icon Use

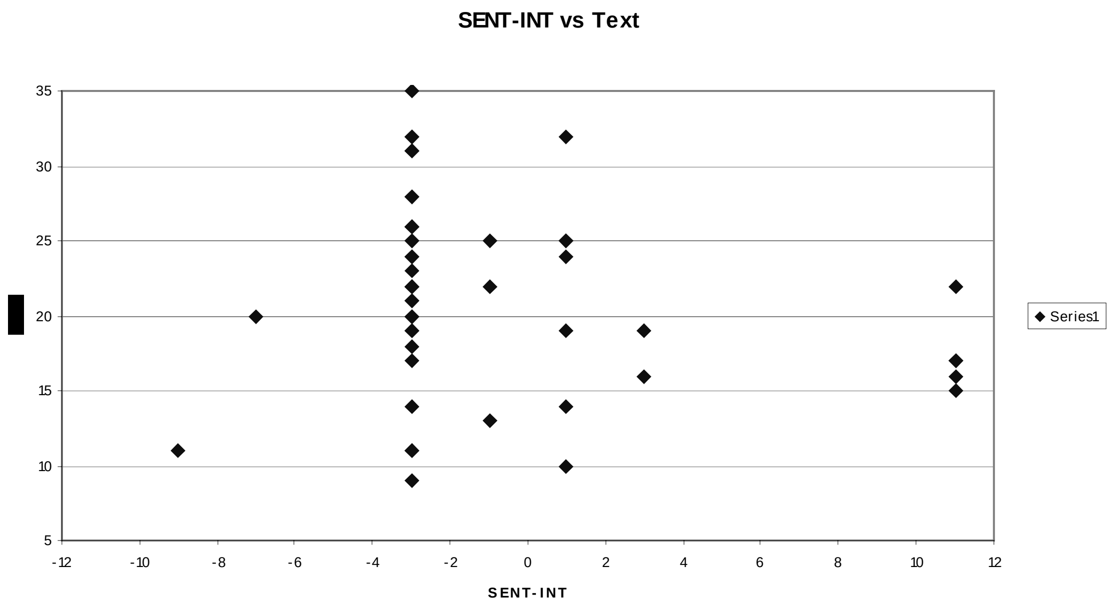

Figure 24 Sent-Int vs. Text Use

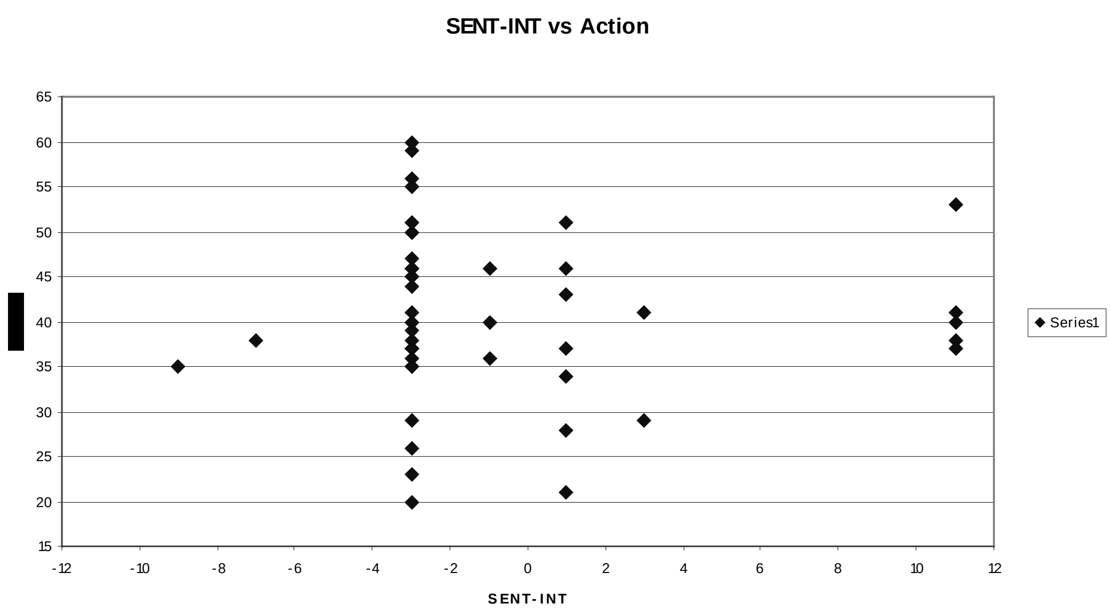

Figure 25 Sent-Int vs. Total Actions

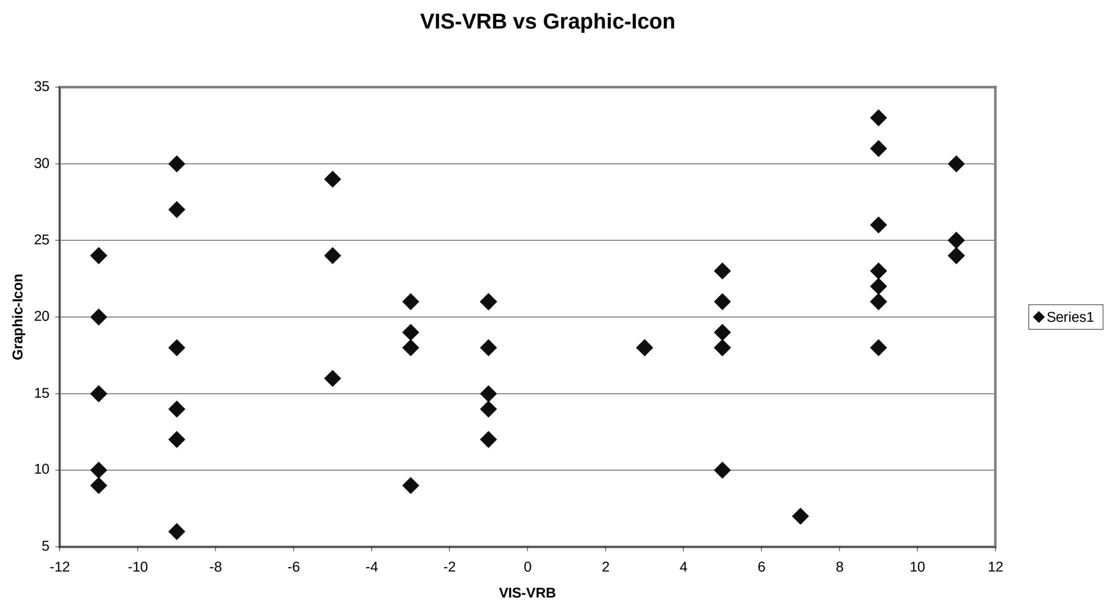

Figure 26 Vis-Vrb vs. Graphic Icon Use

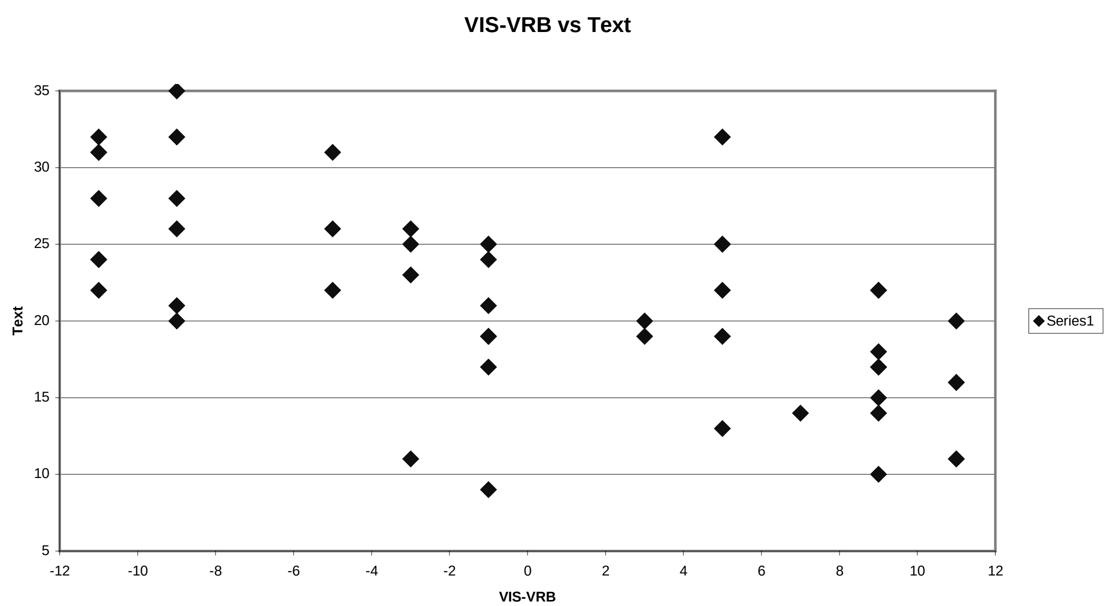

Figure 27 Vis-Vrb vs. Text Use

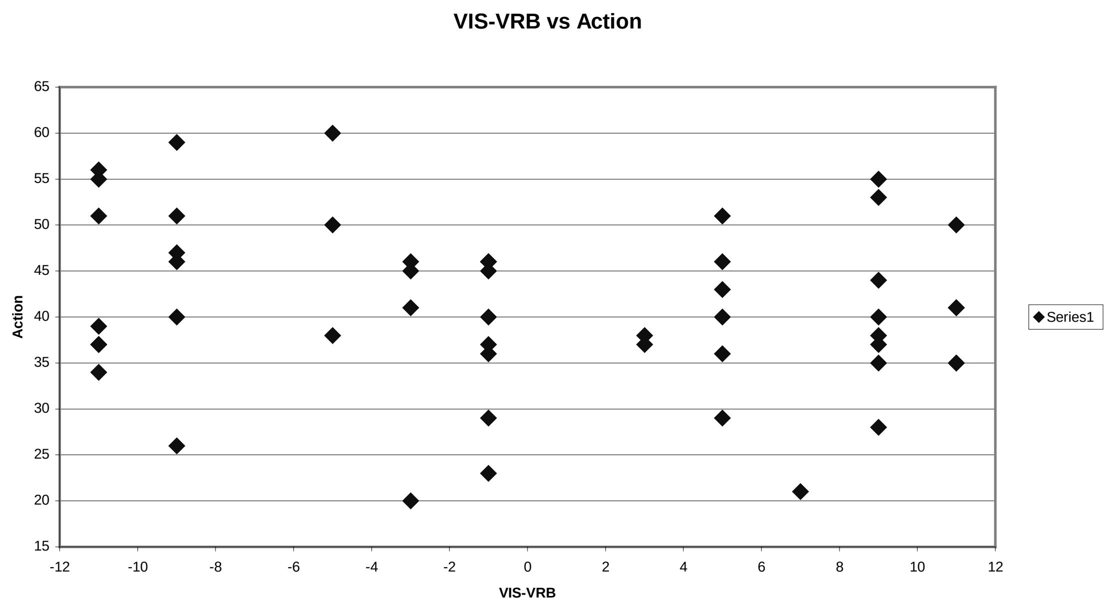

Figure 28 Vis-Vrb vs. Total Actions

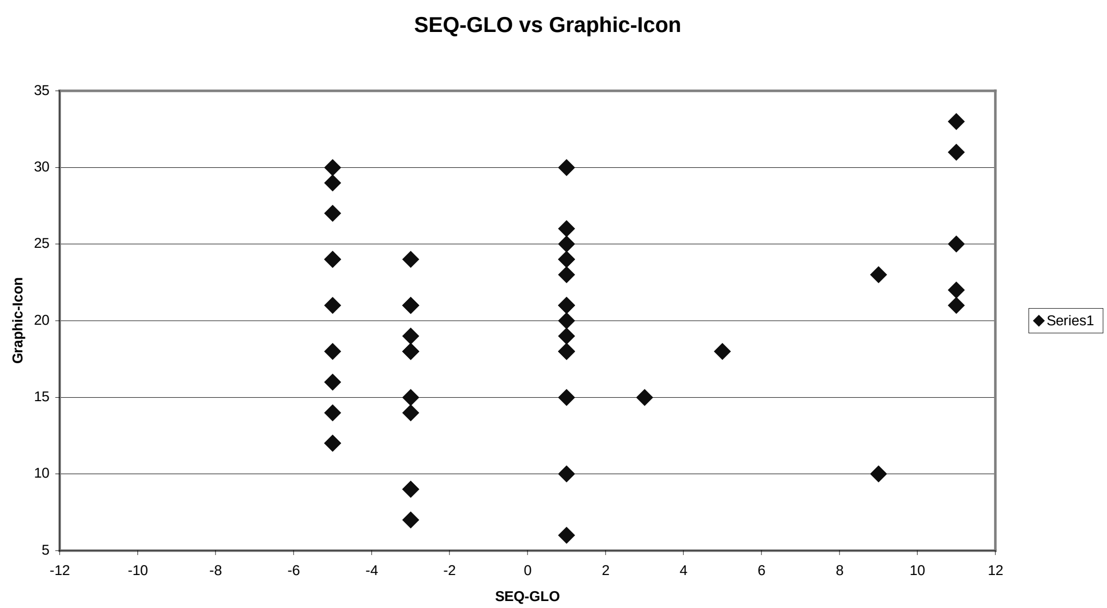

Figure 29 Seq-Glo vs. Graphic Icon Use

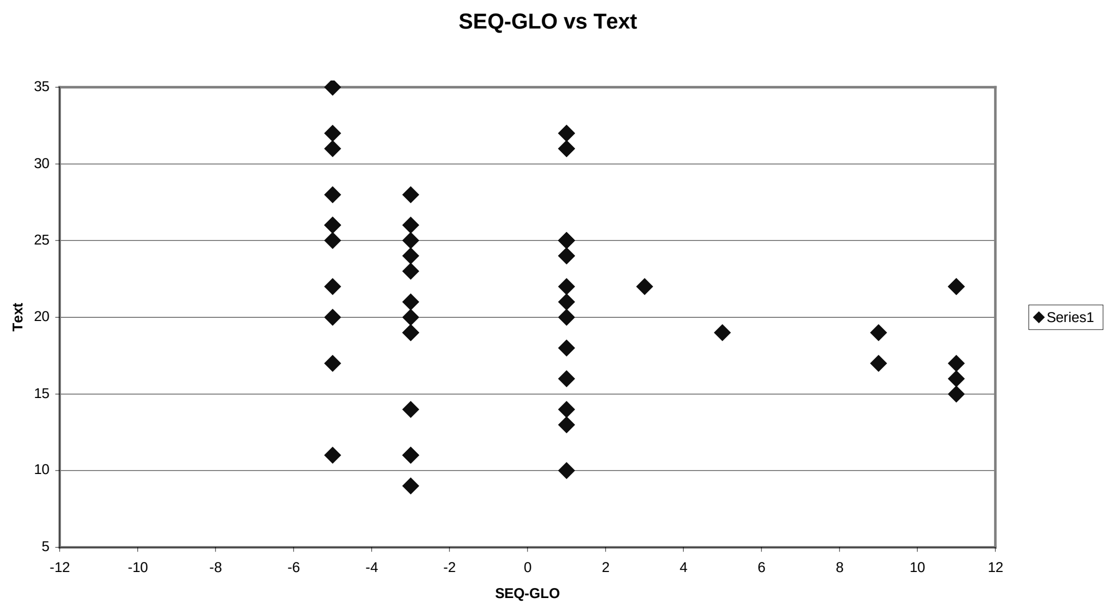

Figure 30 Seq-Glo vs. Text Use

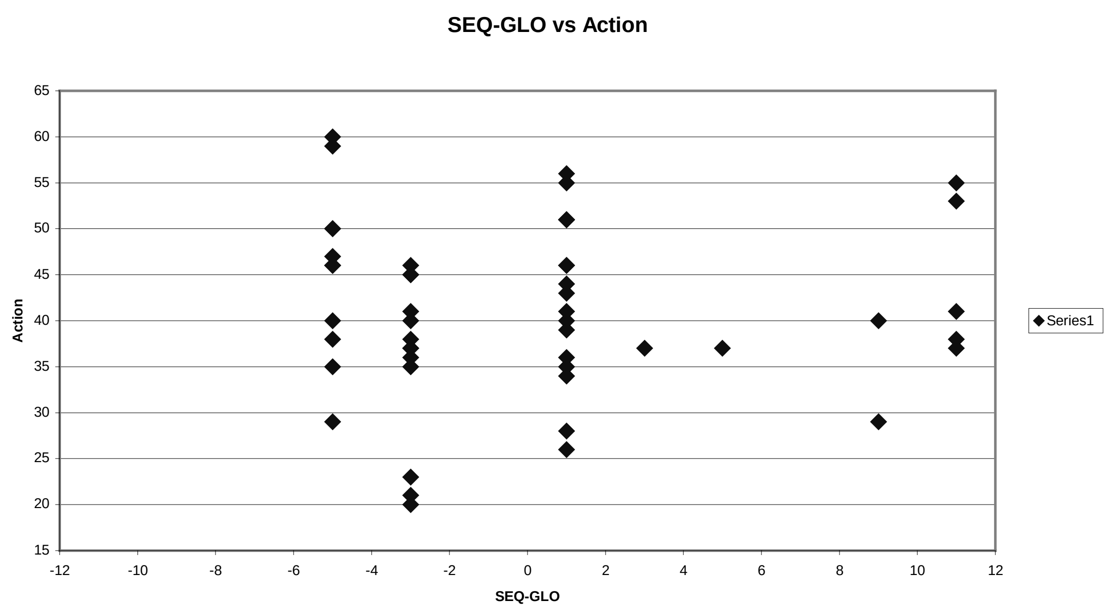

Figure 31 Seq-Glo vs. Total Actions

Appendix J: SAS Statistical Analysis Data

The SAS System - Number of observations 50 - Dependent Variable: **prop_graph**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.31470430	0.07867607	11.42	<.0001
Error	45	0.31003524	0.00688967		
Corrected Total	49	0.62473954			

R-Square	Coeff Var	Root MSE	prop_graph Mean
0.503737	17.47677	0.083004	0.474939

Source	DF	Type III SS	Mean Square	F Value	Pr > F
visvrbnum	1	0.20154803	0.20154803	29.25	<.0001
senintnum	1	0.00554210	0.00554210	0.80	0.3746
seqglonum	1	0.00045856	0.00045856	0.07	0.7976
refactnum	1	0.01834843	0.01834843	2.66	0.1097

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.4899624570	0.01598154	30.66	<.0001
visvrbnum	-.0389645564	0.00720410	-5.41	<.0001
senintnum	-.0153817853	0.01715019	-0.90	0.3746
seqglonum	-.0037241520	0.01443543	-0.26	0.7976
refactnum	-.0177239132	0.01086074	-1.63	0.1097

Model: MODEL1 - Dependent Variable: **prop_graph** Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.28560	0.28560	40.42	<.0001
Error	48	0.33914	0.00707		
Corrected Total	49	0.62474			

Root MSE	0.08406	**R-Square**	0.4571
Dependent Mean	0.47494	**Adj R-Sq**	0.4458
Coeff Var	17.69828		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.47416	0.01189	39.89	<.0001
visvrbnum	1	-0.03893	0.00612	-6.36	<.0001

Dependent Variable: prop_graph

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	0.37509196	0.03750920	5.86	<.0001
Error	39	0.24964757	0.00640122		
Corrected Total	49	0.62473954			

R-Square	Coeff Var	Root MSE	prop_graph Mean
0.600397	16.84586	0.080008	0.474939

Source	DF	Type III SS	Mean Square	F Value	Pr > F
visvrbnum	1	0.05377492	0.05377492	8.40	0.0061
senintnum	1	0.00002736	0.00002736	0.00	0.9482
visvrbnum*senintnum	1	0.00000313	0.00000313	0.00	0.9825
seqglonum	1	0.01807693	0.01807693	2.82	0.1009
visvrbnum*seqglonum	1	0.00564143	0.00564143	0.88	0.3536
senintnum*seqglonum	1	0.00000783	0.00000783	0.00	0.9723
refactnum	1	0.00853344	0.00853344	1.33	0.2553
visvrbnum*refactnum	1	0.00161392	0.00161392	0.25	0.6184
senintnum*refactnum	1	0.01681337	0.01681337	2.63	0.1131
seqglonum*refactnum	1	0.02818545	0.02818545	4.40	0.0424

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.4781836917	0.03749619	12.75	<.0001
visvrbnum	-.0453712161	0.01565388	-2.90	0.0061
senintnum	-.0037955264	0.05805733	-0.07	0.9482
visvrbnum*senintnum	-.0003793556	0.01716224	-0.02	0.9825
seqglonum	-.0375334786	0.02233510	-1.68	0.1009
visvrbnum*seqglonum	-.0095867720	0.01021196	-0.94	0.3536
senintnum*seqglonum	0.0006653161	0.01902615	0.03	0.9723
refactnum	-.0186639054	0.01616486	-1.15	0.2553
visvrbnum*refactnum	0.0038227671	0.00761321	0.50	0.6184
senintnum*refactnum	-.0455810090	0.02812470	-1.62	0.1131
seqglonum*refactnum	0.0369406976	0.01760451	2.10	0.0424

The SAS System - Model: **MODEL1** - Dependent Variable: **prop_graph**

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.31470	0.07868	11.42	<.0001
Error	45	0.31004	0.00689		
Corrected Total	49	0.62474			

Root MSE	0.08300	**R-Square**	0.5037
Dependent Mean	0.47494	**Adj R-Sq**	0.4596
Coeff Var	17.47677		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	1	0.48996	0.01598	30.66	<.0001	0
visvrbnum	1	-0.03896	0.00720	-5.41	<.0001	1.41980
senintnum	1	-0.01538	0.01715	-0.90	0.3746	2.14225
seqglonum	1	-0.00372	0.01444	-0.26	0.7976	2.35915
refactnum	1	-0.01772	0.01086	-1.63	0.1097	1.23817

Model: **MODEL1 -** Dependent Variable: **prop_graph**

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.10528	0.10528	9.73	0.0031

Error	48	0.51946	0.01082
Corrected Total	49	0.62474	

Root MSE	0.10403	**R-Square**	0.1685
Dependent Mean	0.47494	**Adj R-Sq**	0.1512
Coeff Var	21.90368		

Parameter Estimates

Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Variance Inflation**
Intercept	1	0.51080	0.01867	27.36	<.0001	0
refactnum	1	-0.03815	0.01223	-3.12	0.0031	1.00000

The SAS System - Number of observations 50 - Dependent Variable: prop_graph

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	0.30200629	0.10066876	14.35	<.0001
Error	46	0.32273325	0.00701594		
Corrected Total	49	0.62473954			

R-Square	**Coeff Var**	**Root MSE**	**prop_graph Mean**
0.483412	17.63619	0.083761	0.474939

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
refactnum	1	0.01635846	0.01635846	2.33	0.1336
visvrbnum	1	0.06816781	0.06816781	9.72	0.0031
refactnum*visvrbnum	1	0.00153366	0.00153366	0.22	0.6423

Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	0.4927995824	0.01765512	27.91	<.0001
refactnum	-.0169446736	0.01109698	-1.53	0.1336
visvrbnum	-.0315145533	0.01011031	-3.12	0.0031
refactnum*visvrbnum	-.0028159152	0.00602280	-0.47	0.6423

Number of observations 50 - Dependent Variable: prop_graph

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	4	0.31106867	0.07776717	11.16	<.0001
Error	45	0.31367086	0.00697046		
Corrected Total	49	0.62473954			

R-Square	**Coeff Var**	**Root MSE**	**prop_graph Mean**
0.497917	17.57894	0.083489	0.474939

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
refactnum	1	0.01994021	0.01994021	2.86	0.0977
visvrbnum	1	0.19766605	0.19766605	28.36	<.0001
visvrbnum*seqglonum	1	0.00190647	0.00190647	0.27	0.6036
seqglonum	1	0.00477010	0.00477010	0.68	0.4125

Standard

Parameter	Estimate	Error	t Value	Pr > |t|
Intercept	0.4958316187	0.01717599	28.87	<.0001
refactnum	-.0185309933	0.01095632	-1.69	0.0977
visvrbnum	-.0383457441	0.00720082	-5.33	<.0001
visvrbnum*seqglonum	0.0028327376	0.00541654	0.52	0.6036
seqglonum	-.0098235431	0.01187504	-0.83	0.4125

Number of observations **50** - Dependent Variable: **prop_graph**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.31470430	0.07867607	11.42	<.0001
Error	45	0.31003524	0.00688967		
Corrected Total	49	0.62473954			

R-Square	Coeff Var	Root MSE	prop_graph Mean
0.503737	17.47677	0.083004	0.474939

Source	DF	Type III SS	Mean Square	F Value	Pr > F
refactnum	1	0.01834843	0.01834843	2.66	0.1097
visvrbnum	1	0.20154803	0.20154803	29.25	<.0001
seqglonum	1	0.00045856	0.00045856	0.07	0.7976
senintnum	1	0.00554210	0.00554210	0.80	0.3746

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.4899624570	0.01598154	30.66	<.0001
refactnum	-.0177239132	0.01086074	-1.63	0.1097
visvrbnum	-.0389645564	0.00720410	-5.41	<.0001
seqglonum	-.0037241520	0.01443543	-0.26	0.7976
senintnum	-.0153817853	0.01715019	-0.90	0.3746

Number of observations **50** - Dependent Variable: **TotalAct**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	192.897243	48.224311	0.53	0.7138
Error	45	4089.922757	90.887172		
Corrected Total	49	4282.820000			

R-Square	Coeff Var	Root MSE	TotalAct Mean
0.045040	23.21840	9.533476	41.06000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
refactnum	1	24.5288520	24.5288520	0.27	0.6060
visvrbnum	1	186.4775841	186.4775841	2.05	0.1589
seqglonum	1	2.0553591	2.0553591	0.02	0.8811
senintnum	1	1.5836089	1.5836089	0.02	0.8956

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	41.68872551	1.83556848	22.71	<.0001
refactnum	-0.64803554	1.24741657	-0.52	0.6060
visvrbnum	1.18520582	0.82743094	1.43	0.1589
seqglonum	0.24932987	1.65798936	0.15	0.8811
senintnum	0.26001219	1.96979503	0.13	0.8956

The SAS System - Dependent Variable: **Kolb**

Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
Model	1	0.01643752	0.01643752	0.02	0.9002
Error	48	49.66356248	1.03465755		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.000331	33.02536	1.017181	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
prop_graph	1	0.01643752	0.01643752	0.02	0.9002

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.002961663	0.62790517	4.78	<.0001
prop_graph	0.162206668	1.28691191	0.13	0.9002

The SAS System - Number of observations 50 - Dependent Variable: Kolb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.57919726	1.57919726	1.58	0.2154
Error	48	48.10080274	1.00210006		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.031787	32.50161	1.001049	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TotalAct	1	1.57919726	1.57919726	1.58	0.2154

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.868446491	0.64382971	6.01	<.0001
TotalAct	-0.019202301	0.01529645	-1.26	0.2154

The SAS System - Number of observations 50 - Dependent Variable: Kolb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1.61927270	0.80963635	0.79	0.4590
Error	47	48.06072730	1.02256867		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.032594	32.83186	1.011221	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TotalAct	1	1.60283518	1.60283518	1.57	0.2168
prop_graph	1	0.04007545	0.04007545	0.04	0.8439

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.755134277	0.86637253	4.33	<.0001
TotalAct	-0.019377005	0.01547706	-1.25	0.2168
prop_graph	0.253686189	1.28145655	0.20	0.8439

The SAS System - Number of observations 50 - Dependent Variable: Kolb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.56401754	0.56401754	0.55	0.4614

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Error	48	49.11598246	1.02324963		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.011353	32.84279	1.011558	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
senintnum	1	0.56401754	0.56401754	0.55	0.4614

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.088481467	0.14351132	21.52	<.0001
senintnum	0.106018334	0.14279910	0.74	0.4614

The SAS System - Number of observations **50** - Dependent Variable: **Kolb**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.18594228	0.18594228	0.18	0.6730
Error	48	49.49405772	1.03112620		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.003743	32.96896	1.015444	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
visvrbnum	1	0.18594228	0.18594228	0.18	0.6730

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.079371817	0.14361306	21.44	<.0001
visvrbnum	-0.031409168	0.07396449	-0.42	0.6730

The SAS System - Number of observations **50** - Dependent Variable: **Kolb**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.14820513	0.14820513	0.14	0.7064
Error	48	49.53179487	1.03191239		
Corrected Total	49	49.68000000			

R-Square	Coeff Var	Root MSE	Kolb Mean
0.002983	32.98152	1.015831	3.080000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
seqglonum	1	0.14820513	0.14820513	0.14	0.7064

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	3.084358974	0.14411990	21.40	<.0001
seqglonum	-0.043589744	0.11502020	-0.38	0.7064

The SAS System - Number of observations **50** - Dependent Variable: **Eachus**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1482.62200	1482.62200	4.66	0.0360

Error	48	15287.45800	318.48871		
Corrected Total	49	16770.08000			

R-Square	Coeff Var	Root MSE	Eachus Mean
0.088409	11.46048	17.84625	155.7200

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Easy	1	1482.622001	1482.622001	4.66	0.0360

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	127.6099343	13.27068178	9.62	<.0001
Easy	7.3586560	3.41059615	2.16	0.0360

The SAS System - Number of observations **50** - Dependent Variable: **Eachus**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	281.24494	281.24494	0.82	0.3701
Error	48	16488.83506	343.51740		
Corrected Total	49	16770.08000			

R-Square	Coeff Var	Root MSE	Eachus Mean
0.016771	11.90227	18.53422	155.7200

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Satisfied	1	281.2449413	281.2449413	0.82	0.3701

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	143.1966874	14.08649367	10.17	<.0001
Satisfied	3.1152519	3.44290610	0.90	0.3701

The SAS System - Number of observations **50** - Dependent Variable: **Eachus**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1673.94388	836.97194	2.61	0.0845
Error	47	15096.13612	321.19439		
Corrected Total	49	16770.08000			

R-Square	Coeff Var	Root MSE	Eachus Mean
0.099817	11.50905	17.92190	155.7200

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Satisfied	1	191.321879	191.321879	0.60	0.4441
Easy	1	1392.698939	1392.698939	4.34	0.0428

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	118.0336748	18.20886016	6.48	<.0001
Satisfied	2.5771376	3.33917567	0.77	0.4441
Easy	7.1534638	3.43535590	2.08	0.0428

The SAS System - Number of observations: **50** - Dependent Variable: **Eachus**

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2162.40636	720.80212	2.27	0.0930

Error	46	14607.67364	317.55812
Corrected Total	49	16770.08000	

R-Square	Coeff Var	Root MSE	Eachus Mean
0.128944	11.44372	17.82016	155.7200

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Satisfied	1	589.4886754	589.4886754	1.86	0.1797
Easy	1	821.3680283	821.3680283	2.59	0.1146
Satisfied*Easy	1	488.4624812	488.4624812	1.54	0.2212

Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	30.40563804	72.93730420	0.42	0.6787
Satisfied	24.44152235	17.93916119	1.36	0.1797
Easy	29.52256761	18.35679432	1.61	0.1146
Satisfied*Easy	-5.56602378	4.48787823	-1.24	0.2212

Vita

Jason E. Rollins was born and raised in Bucks County, Pennsylvania. He graduated Magna Cum Laude from Temple University where he studied Art. He later earned graduate degrees in both Communication and Education from Drexel University. Jason has 10 years of professional experience in Web and software design and usability evaluation including experience with Towers Perrin, Comcast-Spectacor, and ISI ResearchSoft. Also, he has completed educational technology consulting projects for clients including Drexel and Princeton Universities. He is married and lives in Philadelphia, Pennsylvania.